EUROPEAN PATENT OFFICE

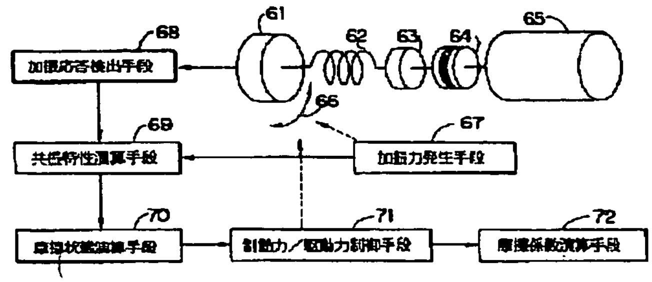
Patent Abstracts of Japan

PUBLICATION NUMBER : 08334454
PUBLICATION DATE : 17-12-96

APPLICATION DATE : 05-06-95
APPLICATION NUMBER : 07138307

APPLICANT : TOYOTA CENTRAL RES & DEV LAB INC;

INVENTOR : SUGAI MASARU;



INT.CL. : G01N 19/02 B22D 11/16 B22D 11/16 B62D 6/00 G01N 3/56 // B62D137:00

TITLE : FRICTION STATE DETECTOR

ABSTRACT : PURPOSE: To precisely detect a friction state with much noise and momentarily changing frictional coefficient.

CONSTITUTION: The friction state detector is provided with an exciting force generating means 67 for exciting a vibration system composed of a road face and a wheel by the exciting force of resonance frequency, an excitation response detection means 68 for detecting response to this exciting force, and a response characteristic calculation means 69 for calculating the resonance characteristics of the vibration system based on the excitation and the excitation response. It is constituted of a friction state calculation means 70 for calculating the friction state based on the calculated resonance characteristics, a braking force/driving force control means 71 for controlling the braking force/driving force so that the calculated friction state is set to the state right before sliding from the calculated friction state, and a friction coefficient calculation means 72 which calculates the maximum friction force value based on this braking/driving forces and finds the friction coefficient by diving this value by the dead load of the device. The friction state is calculated by resonance characteristics sensitively reflecting the friction state so that the friction state can be detected precisely even in a state as with much noise and momentarily changing frictional coefficient.

JP8334454

Publication Title:

Apparatus and method for detecting friction characteristics

Abstract:

An apparatus and method for detecting friction characteristics are disclosed, in which a wheel resonant system includes a vehicle body, a road surface and at least a wheel. A braking force control system exerts a braking force on the wheel. A resonant component detector determines a resonant gain providing the ratio between the amplitude of predetermined frequency component of the braking force and that of the wheel velocity and detects the ratio of the resonant gain to a present reference gain, a deviation calculator calculates the deviation between this ratio and unity, a PI controller controls the braking force control system in such a manner that the deviation coincides
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with zero, and a friction characteristics detector detects the friction characteristics on the basis of the braking force. When the friction force is made to approach a peak value by increasing the braking force, the resonant characteristics undergo a change thereby to reduce the resonant gain. By controlling the braking force in such a manner that the deviation coincides with zero, therefore, the friction characteristics are held at a peak value. This braking force reflects the friction characteristics, and therefore the friction characteristics between the road surface and the wheel can be accurately detected according to the relative magnitude of the braking force.

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(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号

特開平8－334454

(43)公開日　平成８年(1996)12月17日

(51)Int.Cl.[6]	識別記号	庁内整理番号	ＦＩ	技術表示箇所
Ｇ０１Ｎ　19/02			Ｇ０１Ｎ　19/02	Ｃ
				Ｂ
Ｂ２２Ｄ　11/16	１０４		Ｂ２２Ｄ　11/16	１０４Ａ
	１０５			１０５
Ｂ６２Ｄ　6/00			Ｂ６２Ｄ　6/00	

審査請求　未請求　請求項の数５　ＯＬ　（全 13 頁）　最終頁に続く

(21)出願番号　特願平7－138307

(22)出願日　平成７年(1995)６月５日

(71)出願人　000003609
株式会社豊田中央研究所
愛知県愛知郡長久手町大字長湫字横道41番地の１

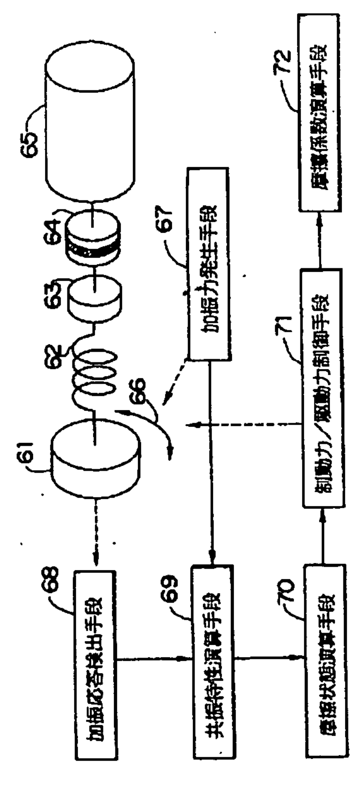
(72)発明者　浅野　勝宏
愛知県愛知郡長久手町大字長湫字横道41番地の１株式会社豊田中央研究所内

(72)発明者　菅井　賢
愛知県愛知郡長久手町大字長湫字横道41番地の１株式会社豊田中央研究所内

(74)代理人　弁理士　中島　淳　（外１名）

(54)【発明の名称】　摩擦状態検出装置

(57)【要約】
【目的】ノイズが多く、摩擦係数が刻々と変化する摩擦状態を正確に検出する。
【構成】路面と車輪からなる振動系を、共振周波数の加振力で加振する加振力発生手段と、この加振力に対する応答を検出する加振応答検出手段と、加振力と加振応答に基づいて、振動系の共振特性を演算する共振特性演算手段と、演算された共振特性に基づいて摩擦状態を演算する摩擦状態演算手段と、演算された摩擦状態を滑りだす直前の状態になるように制動力／駆動力を制御する制動力／駆動力制御手段と、この制動力／駆動力に基づいて最大摩擦力の値を演算し、この値を装置の自重で除算することにより摩擦係数を求める摩擦係数演算手段とから構成される。摩擦状態を敏感に反映する共振特性で摩擦状態を演算するため、ノイズが多く、摩擦係数が刻々と変化する状況でも正確に摩擦状態を検出できる。



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【特許請求の範囲】

【請求項1】　摩擦力の生じる接触面の片面側要素に該接触面と略平行な方向に変位するばね要素を接続し、該ばね要素の他端に慣性体を接続した振動系と、　該振動系の共振周波数又は共振周波数近傍の振動成分を含む加振力により、前記振動系を加振する加振力発生手段と、
該加振力発生手段により加振された振動系の加振応答の状態量を検出する加振応答検出手段と、
前記加振力発生手段により発生された加振力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、
該共振特性演算手段により演算された共振特性に基づいて前記接触面における摩擦状態を演算する摩擦状態演算手段と、
を含む摩擦状態検出装置。

【請求項2】　摩擦力の生じる接触面の片面側要素に接続されて該接触面と略平行な方向に変位するばね要素と、該ばね要素の他端に接続された慣性体とからなり、外力によって加振される振動系と、
前記外力の状態量を検出する外力検出手段と、
前記外力により加振された前記振動系の加振応答の状態量を検出する状態検出手段と、
前記外力検出手段により検出された外力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、
該共振特性演算手段により演算された共振特性に基づいて前記接触面における摩擦状態を演算する摩擦状態演算手段と、
を含む摩擦状態検出装置。

【請求項3】　摩擦力の生じる接触面の片面側要素に該接触面と略平行な方向に変位するばね要素を接続し、該ばね要素の他端に慣性体を接続した振動系と、　該振動系の共振周波数又は共振周波数近傍の振動成分を含む加振力により、前記振動系を摩擦力の発生方向に加振する加振力発生手段と、
該加振力発生手段により加振された前記振動系の加振応答の状態量を検出する加振応答検出手段と、
前記加振力発生手段により発生された加振力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、
前記接触面の片面側要素に作用力を与える作用力発生手段と、
前記共振特性演算手段により演算された共振特性に基づいて、前記接触面が滑りだす直前の状態になるように前記作用力発生手段を制御する最大摩擦力状態制御手段と、
を含む摩擦状態検出装置。

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【請求項4】　摩擦力の生じる接触面の片面側要素に接続されて該接触面と略平行な方向に変位するばね要素と、該ばね要素の他端に接続された慣性体とからなり、外力によって加振される振動系と、
前記外力の状態量を検出する外力検出手段と、
前記外力により加振された前記振動系の加振応答の状態量を検出する状態検出手段と、
前記外力検出手段により検出された外力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、
前記接触面の片面側要素に作用力を与える作用力発生手段と、
前記共振特性演算手段により演算された共振特性に基づいて、前記接触面が滑りだす直前の状態になるように前記作用力発生手段を制御する最大摩擦力状態制御手段と、
を含む摩擦状態検出装置。

【請求項5】　前記最大摩擦力状態制御手段により前記接触面が滑りだす直前の状態になった時の作用力に基づいて、前記接触面における最大摩擦力の値を演算する最大摩擦力演算手段と、
該最大摩擦力演算手段により演算された最大摩擦力の値に基づいて前記接触面の摩擦係数を演算する摩擦係数演算手段と、
をさらに含む請求項3又は請求項4の摩擦状態検出装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は摩擦状態検出装置に係り、特に摩擦力の生じる接触面を有する振動系の共振特性に基づいて摩擦状態を検出し、また接触面が滑りだす直前の摩擦状態になるように制御する摩擦状態検出装置に関する。

【0002】

【従来の技術】摩擦力若しくは摩擦係数を測定する技術、及び摩擦状態を検出して制御を行う技術として以下のようなものがある。

【0003】図7に示すモデルにおいて、質量Mの物体1と被計測面2との間に発生する最大摩擦力 F_{max} は、荷重をW（＝Mg；gは重力加速度）、静止摩擦係数を μ_{stat} とすると、

$$F_{max} = \mu_{stat} \cdot W$$

で表される。ここで、外部から印加される外力 F_{ext} が最大摩擦力 F_{max} 以下であれば、静止状態に留まる。しかし、外力 F_{ext} が一旦最大摩擦力 F_{max} を超えると突然滑りだす。その時の摩擦力 F_{tran} は、動摩擦係数 μ_{trans} により、

$$F_{trans} = \mu_{trans} \cdot W$$

で表される。

【0004】しかし、このように、外力Fext が最大摩擦力Fmax を超えるまでは全く変化がなく、最大摩擦力を超えたと同時に状態が大きく変化するため、滑りだす前に滑りだす直前の状態にあるか否かを知ることは大変難しい。

【0005】そこで、従来の摩擦力測定装置では、事前に外力を加えて滑らせ、その時の最大摩擦力Fmax を調べることにより摩擦力を測定し、さらに最大摩擦力Fmax を装置の自重で除算することにより静止摩擦係数μstat を測定するようにしていた。

【0006】また、鋳造技術の分野では、連続鋳造用の鋳型を振動台に固定支持すると共に加振ビームを介して加振源に連結し、この加振源の動作により加振ビームを所定の支点回りに揺動させ、この鋳型を加振しつつ行われる鋳片の引き抜きに際し、鋳片と鋳型との間に作用する摩擦力を測定する技術がある。これらの技術は、鋳型と鋳片との間の摩擦力が加振源の負荷に影響を与えることを利用するもので、鋳型の振動系の特性を伝達関数にて表現し、この伝達関数に基づいて鋳型と鋳片との間の摩擦力を測定するというものである。このような鋳造技術の分野における摩擦力測定技術で特に演算速度の向上と正確さを期した技術として、特開平4－84652号公報に開示された技術などがある。

【0007】特開平4－84652号公報の技術は、加振された鋳型から鋳片を引き抜くに際し、両者間に作用する摩擦力を、加振ビームの支点よりも鋳型寄りの部分をモード分解法にて定式化した状態空間モデルに従い、加振する際に鋳型に働く揺動トルクと、加振により鋳型に生じる変位とに基づいて演算するというものである。なお、鋳型に働く揺動トルクを正確に求めるため、加振シリンダなどの加振源が発する加振力及び加振ビームの支点よりも加振源よりの部分において加振ビームに生じる歪みを検出し、検出された加振力を加振ビームに生じた歪みで補正して揺動トルクを演算するという方法を用いている。このように、この技術では、加振ビームの支＊＊点から加振対象となる鋳型までの間を支点に作用する揺動トルクにより振動台と鋳型とからなる集中質量を加振する撓み梁として簡略にモデル化することにより高速演算を達成し、さらに揺動トルクを演算する際に、加振力を加振ビームの歪みで補正することによって正確な摩擦力の測定を可能にしている。

【0008】また、自動車の制御技術の分野で、車輪と路面との間の摩擦係数を測定し、この摩擦係数に基づいて制御を行う技術として、特開平4－230472号公報に開示された電子制御パワーステアリング装置などがある。

【0009】特開平4－230472号公報に開示された摩擦係数の測定方法は、コントローラからソレノイドバルブへ加振信号を入力することにより例えば後輪を±1mm相当の舵角、周波数2Hzで周期的に転舵し、この周期的な転舵により後輪に発生したコーナリングフォースやセルフアライングトルクに対する反力をロードセル等の反力センサにより検出し、検出された反力の値に基づいてコーナリングパワーやセルフアライニングパワーを演算し、これらのパワーと路面摩擦係数との関係に基づいて演算結果により路面摩擦係数を計測するというものである。

【0010】また、路面と車輪との摩擦状態を推測して、接触面が滑りだす直前の状態になるようにブレーキ力を制御することにより、急ブレーキをかけても車輪がロックされてスリップすることを防ぐ技術としてアンチロックブレーキ制御装置がある。

【0011】ここで、車両がある速度で走行している時、ブレーキをかけていくと車輪と路面との間にスリップが生じるが、車輪と路面との間の摩擦係数μは、下記の（1）式で表されるスリップ率Sに対し、図9のように変化することが知られている。なお、v_{v*}は実車体速度、v_{w} は車輪速度である。

【0012】

$$S=(v_{v*}-v_{w})/v_{v*} \quad \cdots (1)$$

このμ－S特性では、あるスリップ率（図9のA2領域）で摩擦係数μがピーク値をとるようになる。

【0013】そこで、従来のアンチロックブレーキ制御装置では、車体速度と車輪速度とからスリップ率を検出し、摩擦係数μがピーク値をとるようなスリップ率になるようにブレーキ力を制御するようにしていた。

【0014】

【発明が解決しようとする課題】しかしながら、上記従来の摩擦力検出装置では、滑ることが許されない場合や摩擦係数が変化する場合などにおいて、摩擦状態が現在いかなる状態にあるのかをリアルタイムに検出することが極めて困難になる。このような例として、摩擦力を検出して荷物が滑り落ちない必要最小限の力で荷物を把持する荷物把持装置がある。

【0015】また、特開平4－84652号公報の摩擦力測定装置では、揺動トルクにより振動している集中質量で近似された鋳型の線形モデルを仮定し、単に揺動トルクと鋳型の変位に基づいて、鋳型の振動に影響を与えている摩擦力を演算するため、ノイズ等の影響を受けやすい、という問題がある。また、上記の仮定を満たさない条件下では、このモデルでは摩擦力の正確な測定ができなくなるため、応用範囲がきわめて狭いという問題が生じる。仮に条件に合ったモデルを構築できたとしてもモデルによっては複雑な演算が必要となる場合が多く、かかる場合にはリアルタイムに摩擦力を演算できなくなるという新たな問題も生じる。

【0016】また、特開平4－230472号公報に開示された摩擦係数の測定方法では、、車輪を周期的に転

舵してコーナリングフォース等を発生させ、これに対する車輪の反力を検出する必要があり、測定システムが複雑になるという問題がある。さらに、コーナリングパワー等と路面摩擦係数との関係を所定のモデルで仮定しているため、ノイズに弱いという問題もある。

【００１７】また、従来のアンチロックブレーキ制御装置では、運転中のタイヤと路面との間の摩擦係数μが時々刻々変化し、かつノイズも多いので、摩擦係数μがピークとなるスリップ率も変化し、適切なブレーキ制御はきわめて困難となる。

【００１８】本発明は上記従来の問題点を解消するためになされたもので、システム構成や条件の依存度の大きいモデルを仮定し、単なる振動特性や変位応答等に基づいて摩擦状態を検出するのではなく、摩擦力をより敏感に反映する共振状態を積極的に作りだし、この共振状態の共振特性に着目して摩擦状態を演算することにより、ノイズが多く、また摩擦状態が時々刻々と変化する状況においても摩擦状態を正確に検出できると共に、適用範囲の広いシンプルな構成の摩擦状態検出装置を提供することを目的とする。

【００１９】

【課題を解決するための手段】上記目的を達成するために、請求項１の発明は、摩擦力の生じる接触面の片面側要素に該接触面と略平行な方向に変位するばね要素を接続し、該ばね要素の他端に慣性体を接続してなる振動系と、該振動系の共振周波数又は共振周波数近傍の振動成分を含む加振力により、前記振動系を加振する加振力発生手段と、該加振力発生手段により加振された振動系の加振応答の状態量を検出する加振応答検出手段と、前記加振力発生手段により発生された加振力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、該共振特性演算手段により演算された共振特性に基づいて前記接触面における摩擦状態を演算する摩擦状態演算手段と、を含んで構成されている。

【００２０】請求項２の発明は、摩擦力の生じる接触面の片面側要素に接続されて該接触面と略平行な方向に変位するばね要素と、該ばね要素の他端に接続された慣性体とからなり、外力によって加振される振動系と、前記外力の状態量を検出する外力検出手段と、前記外力により加振された前記振動系の加振応答の状態量を検出する状態検出手段と、前記外力検出手段により検出された外力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、該共振特性演算手段により演算された共振特性に基づいて前記接触面における摩擦状態を演算する摩擦状態演算手段と、を含んで構成されている。

【００２１】請求項３の発明は、摩擦力の生じる接触面の片面側要素に該接触面と略平行な方向に変位するばね要素を接続し、該ばね要素の他端に慣性体を接続してなる振動系と、該振動系の共振周波数又は共振周波数近傍の振動成分を含む加振力により、前記振動系を摩擦力の発生方向に加振する加振力発生手段と、該加振力発生手段により加振された前記振動系の加振応答の状態量を検出する加振応答検出手段と、前記加振力発生手段により発生された加振力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、前記接触面の片面側要素に作用力を与える作用力発生手段と、前記共振特性演算手段により演算された共振特性に基づいて、前記接触面が滑りだす直前の状態になるように前記作用力発生手段を制御する最大摩擦力状態制御手段と、を含んで構成されている。

【００２２】請求項４の発明は、摩擦力の生じる接触面の片面側要素に接続されて該接触面と略平行な方向に変位するばね要素と、該ばね要素の他端に接続された慣性体とからなり、外力によって加振される振動系と、前記外力の状態量を検出する外力検出手段と、前記外力により加振された前記振動系の加振応答の状態量を検出する状態検出手段と、前記外力検出手段により検出された外力の状態量と、前記加振応答検出手段により検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する共振特性演算手段と、前記接触面の片面側要素に作用力を与える作用力発生手段と、前記共振特性演算手段により演算された共振特性に基づいて、前記接触面が滑りだす直前の状態になるように前記作用力発生手段を制御する最大摩擦力状態制御手段と、を含んで構成されている。

【００２３】請求項５の発明は、請求項３又は請求項４の最大摩擦力状態制御手段により前記接触面が滑りだす直前の状態になった時の作用力に基づいて、前記接触面における最大摩擦力の値を演算する最大摩擦力演算手段と、該最大摩擦力演算手段により演算された最大摩擦力の値に基づいて前記接触面の摩擦係数を演算する摩擦係数演算手段と、をさらに含んで構成したものである。

【００２４】

【作用】まず、本発明の原理を図８の振動系１５をモデルにして説明する。図８に示すように、振動系１５は、質量M_aの慣性体１１、この慣性体１１と接触面１０を介して接触する質量M_bの慣性体１２、慣性体１１の一端に取り付けられたばね定数Ｋのばね要素１３、このばね要素の他端に取り付けられた質量M_cの慣性体１４から構成されている。

【００２５】振動系１５は、接触面１０で発生する摩擦力が最大摩擦力以内で接触面１０が滑っていない状態では、慣性体１１の振動に慣性体１２が連動して振動するため、質量（M_a+M_b）とばね定数Ｋのばねと質量M_cとからなる２慣性系と等価になる。従って、摩擦力が最大摩擦力以内の場合における振動系１５における共振

周波数f_1は、

$$f_1 = \sqrt{\{(Ma + Mb + Mc)K / (Ma + Mb)Mc\}} / 2\pi \quad \cdots (2)$$

となる。また、他方の慣性体１２が固定端であれば、（２）式の共振周波数f_1は、

$$f_1 = \sqrt{(K/Mc)} / 2\pi \quad \cdots (3)$$

に近似できる。

【００２６】これに対し、摩擦力が最大摩擦力を超えて滑り出した状態では、慣性体１１の振動に慣性体１２が追随できず、その慣性の影響が小さくなるため、振動系１５は質量Ma と質量Mc からなる２慣性系と等価となり、その共振周波数f_2は、

$$f_2 = \sqrt{\{(Ma + Mc)K / Ma\,Mc\}} / 2\pi \quad \cdots (4)$$

となる。

【００２７】ここで、この振動系１５を接触面１０と平行な方向に共振周波数f_1又はf_1近傍の周波数の加振力１６で微小振動させた場合を想定する。接触面１０が滑っていない状態のときは、振動系１５の共振周波数はf_1なので、振動系１５において、周波数f_1の振動成分は増幅される。すなわち、振動系１５は周波数f_1近傍の振動成分が強く現れる共振状態となる。なお、振動系１５の共振特性を表すものとして、例えば加振力１６の最大振幅に対する振動系１５の振動成分の最大値との比で表される共振ゲインがある。この共振ゲインは、共振状態の場合には１より遙に大きくなり、共振状態でない場合には、共振状態と比較して小さくなる。

【００２８】一方、接触面１０で摩擦力と反対方向の力が最大摩擦力に近づき、滑りだす直前までくると、加振力１６による振動と慣性体の振動とに位相差が出始め、共振ゲインは急激に減少する。

【００２９】そして、接触面１０が完全に滑っている状態に移行すると、振動系１５の共振周波数はf_2に一致するので、加振力１６により与えられた周波数f_1の振動成分は減衰し、振動系１５は共振しなくなる。

【００３０】また、振動系１５をf_2近傍の周波数の加振力１６で加振する場合には、接触面１０が滑っていない状態のとき、振動系１５は共振せず、接触面１０が滑りだすと、振動系１５は周波数f_2の振動成分が強く現れる共振状態となる。

【００３１】また、加振力１６がf_1とf_2近傍の周波数の振動成分を共に含む場合、振動系１５は、接触面１０が滑っていない状態と滑っている状態のいずれの場合でも共振するが、振幅がピークとなる共振周波数が変化することになる。

【００３２】なお、上述の慣性体が直線に沿って振動する振動系のモデルは、回転振動系にも容易に拡張できる。この回転振動系のモデルとして例えば図１０に示すように、重量Wの車体１１２を備えた車両が速度ｖで走行している時の車輪での振動現象、すなわち車体と車輪と路面とによって構成される振動系がある。そこで、この振動系の振動現象を、車輪回転軸で等価的にモデル化した図１１に示すモデルを参照して説明する。

【００３３】ここで、ブレーキ力（制動力）は、路面と接するタイヤのトレッド１１５の表面を介して路面に作用するが、このブレーキ力は実際には路面からの反作用として車体１１２に作用するため、車体重量の回転軸換算の等価モデル１１７はタイヤのトレッドと路面との間の摩擦要素１１６を介して車輪１１３と反対側に連結したものとなる。これは、シャシーダイナモ装置のように、車輪下の大きな慣性、すなわち車輪と反対側の質量で車体の重量を模擬することができることと同様である。

【００３４】図１０、図１１でタイヤリムを含んだ車輪１１３の慣性をJ_w、リムとトレッド１５との間のばね要素１１４のばね定数をK、トレッド１１５の慣性をJ_t、トレッド１１５と路面との間の摩擦要素１１６の摩擦係数をμ、車体１１２の重量の回転軸換算の等価モデル１１７の慣性をJ_vとすると、系全体の特性は次の（５）～（７）のようになる。なお、以下では時間に関する１階微分ｄ／ｄｔを「’」で表し、時間に関する２階微分d^2/dt^2を「”」で表す。

【００３５】

$$J_w\,\theta_w'' = -T + K(\theta_t - \theta_w) \quad \cdots (5)$$

$$J_t\,\theta_t'' = -K(\theta_t - \theta_w) + \mu WR \quad \cdots (6)$$

$$J_v\,\omega_v' = -\mu WR \quad \cdots (7)$$

ここで、

$$w_w = \theta_w' \quad \cdots (8)$$

$$J_v = R^2 W \quad \cdots (9)$$

$$\omega_v = v/r \quad \cdots (10)$$

であり、θ_wは車輪１１３の回転角、θ_w''は車輪１１３の回転角加速度、w_wは車輪１１３の回転角速度、θ_tはトレッド１１５の回転角、θ_t''はトレッド１１５の回転角加速度、ω_vは車体等価モデル１１７の回転軸換算の回転角速度、Ｔは車輪１１３に加えられる制動トルク、Ｗは車体の重量、Ｒは車輪半径である。制動トルクＴは実際にはブレーキバルブの圧力P_bの制御によって行う。

【0036】タイヤがグリップしている時は、トレッド115と車体等価モデル117とが直結されていると考えると、車体等価モデル117の慣性とトレッド115＊＊の慣性との和の慣性と車輪113の慣性とが共振し、この時の車輪共振系の共振波数 f_1 は、

$$f_1 = \sqrt{\{(J_w + J_t + J_v)K / J_w(J_t + J_v)\}} / 2\pi \quad \cdots (11)$$

となり、式（2）と全く同じ形式となる。この状態は図9上では領域A1 に対応する。

【0037】逆に、タイヤの摩擦係数 μ がピーク μ に近付く場合には、タイヤ表面の摩擦係数 μ がスリップ率Ｓに対して変化し難くなり、トレッド115の慣性の振動※※に伴う成分は車体等価モデル117に影響しなくなる。つまり等価的にトレッド115と車体等価モデル117とが分離され、トレッド115と車輪113とが共振を起こすことになる。この時の車輪共振系の共振周波数 f_2 は、

$$f_2 = \sqrt{\{(J_w + J_t)K / J_w J_t\}} / 2\pi \quad \cdots (12)$$

となり、式（4）と全く同じ形式となる。この状態は図9の領域Ａ２に対応し、一般にピーク μ の点に達すると瞬時に領域Ａ３へと遷移してタイヤがロックする。一★★方、共振周波数における車輪速度のゲインのピークもピーク μ 直前で急激に減少する。

【0038】各慣性の大小関係は、

$$J_t < J_w < J_v \quad \cdots (13)$$

であり、これより、

$$f_1 < f_2 \quad \cdots (14)$$

になる。つまり、タイヤがロックに至る場合、車輪共振系の共振周波数が高周波側にずれることになる。また、この共振周波数の変化はピーク μ 付近で急激に発生する。

【0039】モデルを簡単化し、トレッド115の慣性 J_t を無視した場合でもピーク μ 状態に近づくと車輪共振系の共振周波数及び車輪速度のゲインのピークの変化は起こり、同様の解析が可能である。

【0040】以上のように、接触面の摩擦状態によって、振動系15や車輪共振系の共振の有無、共振周波数の変化、加振力のどの周波数成分がどの程度の共振ゲインで増幅又は減衰したか等といった共振特性が大きく変わる。逆に、この共振特性を検出すれば、接触面の摩擦状態（滑りだす直前の状態など）や摩擦係数などが演算できることになる。

【0041】そこで、請求項1の発明では、摩擦力の生じる接触面の片面側要素に該接触面と略平行な方向に変位するばね要素を接続し、該ばね要素の他端に慣性体を接続した振動系を、加振力発生手段が、この振動系の共振周波数又は共振周波数近傍の振動成分を含む加振力によって加振する。なお、ばね要素の変位方向は、接触面と略平行な方向（接触面内を含む）であれば任意好適に設定できる。次に、加振応答検出手段が、加振された振動系の加振応答の状態量を検出する。この加振応答は、例えば加振力による慣性体の加速度等であり、この状態量として加速度の振動成分の周波数分布等がある。次に、共振特性演算手段が、加振力の状態量と、検出された加振応答の状態量とに基づいて、前記振動系の共振特性を演算する。そして、摩擦状態演算手段が、演算された共振特性に基づいて前記接触面における摩擦状態を演算する。この演算された摩擦状態により、例えば接触面が滑っていない状態、滑りだす直前の状態、及び滑っている状態のいずれの状態にあるかを定量的に識別、判定できることになる。また、振動系の共振特性を利用しているので、検出感度が高くノイズ等の外乱の影響も受けにくい、という利点がある。

【0042】この発明において、図8の振動系15で接触面10が滑りだす直前の摩擦状態にあるか否かを演算する場合には、例えば接触面10が滑っていないときの振動系15の共振周波数 f_1 又は f_1 近傍の周波数で振動系15を加振し、周波数 f_1 で振動する成分の共振ゲインを演算し、この共振ゲインが第1の基準値より小さくなったときに摩擦状態が滑りだす直前の状態と判定する。また、接触面が滑っているときの共振周波数 f_2 で加振して、この周波数で振動する成分の共振ゲインが第2の基準値より大きくなったとき、滑りだす直前の状態と判定しても良い。さらに、少なくとも共振周波数 f_1 及び f_2 の2つの振動成分を含む加振力で加振し、共振周波数の値の変化に基づいて摩擦状態を演算しても良い。

【0043】また、振動系にホワイトノイズ等のような周波数特性を持つ外力が常時入力しているような場合には、加振力発生手段により加振力を与えなくても、振動系は摩擦状態に特有な共振特性で振動する。

【0044】そこで、請求項2の発明では、外力検出手段が外力の状態量を検出し、応答振動検出手段が外力に対する振動系の応答振動の状態量を検出する。次に、共振特性演算手段が、検出された外力と応答振動の状態量とに基づいて、共振特性を演算する。そして、摩擦状態演算手段が、演算された共振特性に基づいて接触面における摩擦状態を演算する。このように外力により振動系が共振を起こす場合には、加振力発生手段を省略でき、装置をシンプルに構成できる。

【0045】また、上記のような共振特性に基づく摩擦状態検出の原理は、接触面が滑りだす直前の状態、すなわち最大摩擦力を保持するように制御する装置にも応用

することができる。

【0046】そこで、請求項3の発明では、加振力発生手段が、この振動系の共振周波数又は共振周波数近傍の振動成分を含む加振力により、振動系を加振する。次に、加振応答検出手段が、加振された振動系の加振応答の状態量を検出し、共振特性演算手段が、加振力の状態量と検出された加振応答の状態量とに基づいて、振動系の共振特性を演算する。また、接触面の片面側要素には作用力発生手段により作用力が与えられており、この作用力は、演算された共振特性に基づいて接触面が滑りだす直前の状態になるように最大摩擦力状態制御手段により制御される。これにより、例えば荷物を把持して上方につり上げて移動させる装置などでは、荷物を把持する把持力（作用力）が、荷物との接触面が滑りだす直前の摩擦状態になるように制御されるため、不必要に大きな把持力で荷物を破壊するおそれを回避できる。なお、この作用力の態様として、把持力の他に、車輪等を回転させるための駆動力、車輪等に作用するブレーキカのような制動力等がある。車輪と路面との摩擦状態が滑りだす直前の状態になるようにブレーキ力を制御すれば、アンチロックブレーキ制御装置にも応用できる。

【0047】また、請求項2の発明のように振動系にホワイトノイズ等のような周波数特性を持つ外力が常時入力しているような場合には、加振力発生手段により加振力を与えなくても、振動系は摩擦状態に特有な共振特性で振動する。

【0048】そこで、請求項4の発明では、外力検出手段が外力の状態量を検出し、応答振動検出手段が外力に対する振動系の応答振動の状態量を検出する。次に、共振特性演算手段が、検出された外力と応答振動の状態量とに基づいて、共振特性を演算する。また、接触面の片面側要素には作用力発生手段により作用力が与えられており、この作用力は、演算された共振特性に基づいて接触面が滑りだす直前の状態になるように最大摩擦力状態制御手段により制御される。このように外力により振動系が共振を起こす場合には、加振力発生手段を省略でき、装置をシンプルに構成できる。

【0049】また、請求項3又は請求項4の発明のように、接触面が滑りだす直前の状態に保持されるように作用力が制御される場合、この作用力により接触面に発生する力は最大摩擦力に等しい力となる。従って、作用力に基づいて最大摩擦力の値が演算できる。さらに、最大摩擦力の値がわかれば、これを装置の自重で除算することにより静止摩擦係数が求められる。

【0050】そこで、請求項5の発明では、接触面が滑りだす直前の状態になった時の作用力に基づいて、最大摩擦力演算手段により接触面における最大摩擦力の値を演算する。そして、摩擦係数演算手段により、演算された最大摩擦力の値に基づいて静止摩擦係数を演算する。これにより、摩擦係数が時々刻々と変化していく路面等で計測を行う場合でも、静止摩擦係数を正確かつ連続的に検出することができる。

【0051】

【実施例】

（第1実施例）以下、共振特性を利用した摩擦状態検出装置の実施例について、図面に基づいて詳細に説明する。

【0052】以下で説明する第1実施例は、本発明の摩擦状態検出装置を例えばクレーンのように荷物を把持し移動させる荷物把持装置に応用することにより、荷物を落とすことなく、また、荷物を破損することなく適切な力で把持することを可能にしたものである。この第1実施例に係る荷物把持装置を図1及び図2を参照しつつ説明する。

【0053】図1（A）の正面図が示すように、本実施例に係る荷物把持装置は、荷物21を把持する把持部22、この把持部22に把持力を与えるための把持力発生部23、全体をつり上げるためにこの把持力発生部23に取り付けられたワイヤ24、及びこのワイヤ24を牽引するための牽引装置（図示なし）から構成される。また、この荷物把持装置の外観を側面から見ると、図1（B）のように示され、荷物21を把持する把持力25が、図の示す方向に与えられていることがわかる。

【0054】なお、把持部22と荷物21との接触面に発生する最大摩擦力は、把持力25とこの接触面における静止摩擦係数μstatの積により決定される。従って、把持力25が十分に大きく最大摩擦力が荷物21の荷重以上の時には、荷物21は滑り落ちず、逆に把持力が小さくなって最大摩擦力が荷物21の荷重より小さくなると、荷物21は滑り落ちることになる。

【0055】図2に、把持力25を制御するための制御系と把持部22の詳細な構成を示す。図2に示すように、把持部22は、その外郭部分を構成する質量Mc の慣性体35、及びこの慣性体35に各々ばね定数K／2のばね要素33とばね要素34とを介して質量Mb の荷物21と接触する側に取り付けられた質量Ma の接触部31を含んで構成される。

【0056】なお、接触部31は、ばね要素33とばね要素34を介して水平方向に変位するように取り付けられる。すなわち、本実施例では、ばね要素の変位方向は、接触面30と略平行で、荷物21の荷重に抗する摩擦力の発生方向とは垂直になる。

【0057】また、接触部31と慣性体35との間には、接触部31を、ばね要素33とばね要素34とが変位する方向に加振周波数 f_2 （$=\sqrt{\{(Ma+Mc)K/MaMc\}}/2\pi$）の加振力36を加えて微小加振する加振力発生手段40が取り付けられている。図1（A）に示すように、この加振力36によって荷物21は接触部31と共に、水平方向26に微小振動することになる。この加振力発生手段40は、例えば、ばね要素

３３とばね要素３４の取付け部分に圧電素子を取付け、この圧電素子を電気駆動で変位させることにより容易に実現できる。また、接触部３１、慣性体３５にそれぞれ磁性体とコイルを取付け、電磁石の吸引反発力で微小加振させることによっても容易に実現できる。

【００５８】さらに、接触部３１には、加振力発生手段４０により微小加振された際の接触部３１の応答特性を検出する加振応答検出手段４１が取り付けられている。この応答検出手段４１は、例えば加振力３６による接触部３１の加速度３８を応答特性として計測する加速度計３７により実現できる。

【００５９】また、加振力発生手段４０により与えられる加振力３６、及び加振応答検出手段４１により検出される加速度３８などの応答特性に基づいて荷物２１を把持した把持部２２の共振特性を演算する共振特性演算手段４２が設けられている。この共振特性は、例えば加振力３６の最大振幅に対する加速度３８の振動成分の最大振幅の比（共振ゲイン）、共振周波数の変化などで表される。

【００６０】さらに、共振特性演算手段４２により演算された共振特性に基づいて接触部３１と荷物２１との接触面の摩擦状態を判定する摩擦状態演算手段４３、この判定された摩擦状態に基づいて、把持力発生部２３を制御して把持部２２に印加する把持力を最適に調節する把持力制御手段４４が設けられている。

【００６１】次に、この荷物把持装置の作用について説明する。加振力発生手段４０により与えられる加振力の加振周波数 f_2 は、接触部３１が荷物２１と離れているときの接触部３１、ばね要素３３、ばね要素３４、慣性体３５から成る振動系の共振周波数である。

【００６２】ところで、荷物２１が把持部２２の把持力２５によりしっかりと把持されている時は、加振力３６による接触部３１の微小振動と共に荷物２１が完全に追随して振動するので、この振動系は、質量Ma の接触部３１に荷物２１の質量Mb を加えた振動系と等価となり、共振周波数は f_1 （$=\sqrt{\{(Ma+Mb+Mc)K/(Ma+Mb)Mc\}}/2\pi$）になる。このため、荷物２１がしっかりと把持されている時には、加振周波数 f_2 の加振力ではこの振動系は共振せず、加振応答検出手段４１により検出される加速度３８、そして共振特性演算手段４２により演算される共振ゲインは、共振した場合と比較して小さい値となる。

【００６３】一方、把持部２２の把持力２５が次第に弱まり、接触面３０における最大摩擦力が一定の値以下に小さくなってくると、加振力３６による接触部３１の微小振動に荷物２１が追随できず、質量Mb の影響が小さくなるため、振動系の共振周波数は f_2 に近づいていく。従って、加振応答検出手段４１により検出される加速度３８の周波数 f_2 の振動成分は増幅していき、これにより共振ゲインも次第に増加する。特に、荷物２１が滑り出す直前になると、加速度の加振周波数成分は急激に増加する。

【００６４】共振特性演算手段４２により共振ゲインが演算されると、摩擦状態演算手段４３は、この共振ゲインに基づいて接触面３０における摩擦状態を演算する。例えば、共振ゲインが基準値より小さい場合は滑っていない状態にある摩擦状態を、共振ゲインが基準値以上の場合、滑り出す直前にある摩擦状態を演算する。この摩擦状態を示す演算値により、接触面３０の状態が、滑っていない状態、滑りだす直前の状態、滑りだした状態のいずれにあるかが識別判定できる。なお、本実施例の場合、この摩擦状態演算手段４３は、単に滑りだす直前になったか否かを判定するだけでも良い。

【００６５】そして、把持力制御手段４４は、演算された摩擦状態に基づいて、把持力２５が必要最小限の値に保たれるように把持力発生部２３を制御する。すなわち、滑っていない摩擦状態の場合には、荷物２１がしっかりと把持されているので、把持力２５を減少させるように制御し、滑りだす直前と判定された摩擦状態の場合には、把持力２５を増加させるように制御する。なお、共振特性演算手段４２で演算された共振ゲイン等の共振特性を把持力制御手段４４に伝達するようにし、直接、共振特性の値に基づいて把持力２５を制御するようにしても良い。この場合には、摩擦状態演算手段４３は不要となる。

【００６６】以上のように摩擦状態を連続的にかつ正確に検出できるので、荷物が滑り出す直前の必要最小限の把持力に制御することが可能となる。これにより、必要以上に大きい把持力による荷物の破損を避けることも可能となる。また、摩擦状態により振動系の共振周波数が大きく変動する性質を利用しているため、検出感度が高く外乱の影響も受けにくい。さらに、制御系もシンプルかつ安価に構成でき、信頼性も高いという利点がある。

【００６７】（第２実施例）共振特性を利用した摩擦状態検出の原理を、摩擦係数を計測する摩擦係数計測装置にも応用することができる。これを第２実施例に係る摩擦係数計測装置として図３及び図４を参照しつつ説明する。

【００６８】図３（Ａ）の正面図が示すように、この摩擦状態計測装置は、被計測面５４（路面）にこの計測装置の自重でもって接触するタイヤ５１、このタイヤ５１を支持するための取付けステー５３及び図示しない制御系を含んで構成されている。この取付けステー５３は、この計測装置によって計測された摩擦係数を利用する装置、例えば車体（図示なし）などに取り付けられる。以下では、取付けステー５３は、車体に取り付けられている場合を想定する。

【００６９】また、図３（Ｂ）の側面図が示すように、タイヤ５１のホイール側には、タイヤ５１を回転させるホイールモータ５２が備えられている。

【0070】ここで、図3のように構成された摩擦係数計測装置の制御系全体の構成、及びこの計測装置と被計測面54と車体とから構成される振動系の等価モデルを図4に示す。図4によれば、図3の摩擦係数計測装置の制御系は、慣性モーメントMc のホイールモータ52のトルク指令に共振周波数 f_1 （=√（K／Mc ）／2π）の微小振動成分を重畳させる加振力発生手段67、微小振動成分が重畳されたホイールモータ52の回転速度の振動成分を検出して共振特性を演算する共振特性演算手段69、検出された共振特性に基づいてタイヤ51と被計測面54の摩擦状態を判定する摩擦状態演算手段70、判定された摩擦状態に基づいてホイールモータ52への制動力／駆動力が最大値となるように制御する制動力／駆動力制御手段71、及び制動力／駆動力をこの計測器の自重で除算することにより接触面の静止摩擦係数を計測する摩擦係数演算手段72を含んで構成される。

【0071】また、図4に示された振動系の等価モデルの各要素は、それぞれ図3における次の要素と等価である。慣性体61は慣性モーメントMc のホイールモータ52の回転子、ばね要素62はタイヤ51のタイヤサイドウオールのばね定数Kの捻じればね、慣性体63は慣性モーメントMa のタイヤ51のベルト部に各々相当する。また、接触面64はタイヤ51と被計測面54との接触面に相当し、慣性体65は、ホイールモータ52の固定子部と取付けステー53及びこの計測器が取り付けられた車体の慣性を同軸上の等価慣性モーメントMb として表したものである。なお、図4の等価モデルにおける接触面64の摩擦状態に依存する共振特性は、上述した図11の等価モデルと全く同じ原理に従うので、詳細な説明を省略する。

【0072】次に、本実施例に係る摩擦係数計測装置の作用について、図4の等価モデルを参照して説明する。

【0073】最初に被計測面54をタイヤ51が滑らずに転動している場合を想定する。この場合、この計測装置と被計測面54と車体から構成される振動系は、慣性モーメント（Ma ＋Mb ）と慣性モーメントMc とからなる2慣性系に近似され、その共振周波数は f_1 （=√｛（Ma ＋Mb ＋Mc ）K／（Ma ＋Mb ）Mc ｝／2π）となる。

【0074】ここで、（Ma ＋Mb ）＞＞Mcを考慮すると、

f_1 ＝ √（K／Mc ）／2π

に近似できる。

【0075】加振力発生手段67は、ホイールモータ52へのトルク指令に周波数 f_1 （√（K／Mc ）／2π）の微小振動成分を重畳させる。従って、ホイールモータ52の回転子に相当する慣性体61には、周波数 f_1 で振動する加振トルク66がかかる。接触面が滑らない状態のとき、この振動系の共振周波数と加振トルク66の周波数が一致し、振動系は共振する。

【0076】次に、加振応答検出手段68は、加振トルク66により生じた慣性体61の回転速度の振動成分を検出する。上記のように接触面が滑っていない状態のときは、この加振応答検出手段68により、共振周波数 f_1 の大きな回転速度振動成分が検出される。

【0077】次に、共振特性演算手段69は、共振特性として、共振周波数 f_1 の振動成分の振幅値を演算する。これは、加振トルク66の最大振幅が常に一定値をとる場合に有効である。なお、第1実施例のように、加振トルク66の最大振幅に対する回転速度の振動成分の最大値との比（共振ゲイン）を求めても良い。

【0078】そして、摩擦状態演算手段70は、共振特性に基づいて、接触面の摩擦状態を演算する。例えば、振幅値が基準値を超えた場合は滑っていない状態にある摩擦状態を、振幅値が基準値より小さい場合は、滑りだした摩擦状態を演算する。なお、この場合には、大きな回転速度振動成分が現れているので、演算された摩擦状態により接触面は滑っていないと判定される。

【0079】次に、制動力／駆動力制御手段71は、演算された摩擦状態に基づいて、接触面が滑る直前の摩擦状態になるように、タイヤ51を介して被計測面54に作用する制動力／駆動力を制御する。すなわち、この装置がある速度で走っている車体等に取り付けられている場合には、タイヤ51の回転を抑えるようなブレーキ力を制動力として与え、逆に、駆動力を持たない装置に取り付けられていたり、単独の場合には、ホイールモータ52によりタイヤ51を回転させるための駆動力を与える。なお、駆動力を増加させると、これに抗する摩擦力が最大摩擦力まで直ちに増加するように、この計測装置に大きな負荷をかけておいても良い。

【0080】上記のように接触面が滑っていない状態と判定された場合には、制動力／駆動力制御手段71は、制動力／駆動力を増加させるように制御する。これにより、制動力／駆動力に抗する摩擦力は増大する。

【0081】ここで、スリップ速度（タイヤ51のトレッドと被計測面54との相対速度）に対する制動力／駆動力の関係を図5に示す。図5において、この領域（A）のスリップ速度の範囲が接触面64が滑っていない状態に対応している。図より領域（A）において制動力／駆動力はスリップ速度の増加と共に増加していることがわかる。なお、本来滑っていないはずの領域（A）でスリップ速度が0より大きくなるのは、タイヤ51のトレッドが接地してから離れるまでの間に、トレッド自体が弾性変形するためで、接触面64は滑っていないが、車体速度とタイヤ51の回転速度との関係で見ると、あたかも滑っているかのように見えるからである。

【0082】このように接触面が滑っていないと判定された場合には、制動力／駆動力は増加していくが、この力が最大摩擦力を超えるようになると接触面64は実際

に滑りだすようになる。図5では、制動力／駆動力がピークに達した以降の領域（B）が、接触面64が実際に滑りだす状態に相当する。

【0083】接触面が滑りだすと、慣性体65は周波数 f_1 の振動に追随できず、その慣性モーメントMb の影響が小さくなるので、この振動系は慣性モーメントMa と慣性モーメントMc とからなる2慣性系に近似され、共振周波数は f_2 （$=\sqrt{\{(Ma+Mc)K/Ma\,Mc\}}/2\pi$）となる。これより、加振力発生手段67が周波数 f_1 の加振トルク66で微小加振しても振動系は共振せず、加振応答検出手段68により検出された回転速度の振動成分は小さくなる。そして、共振特性演算手段69により演算された最大振幅値が減少して基準値以下となると、摩擦状態演算手段70は、接触面が滑っている状態の摩擦状態を演算する。この摩擦状態に基づいて制動力／駆動力制御手段71は、制動力／駆動力が減少するように制御する。図5の例では、領域（B）においてスリップ速度の増加と共に、制動力／駆動力が減少していくことがわかる。

【0084】以上のように、接触面64が滑っていないと判定したときは、制動力／駆動力を増加させるように制御し、接触面64が滑っていると判定したときは、制動力／駆動力を減少させるように制御することにより、接触面の摩擦状態が滑る直前の状態に保持される。すなわち、制動力／駆動力によりタイヤのトレッドにかかる力の値（図7のピークに対応）は、接触面64における最大摩擦力付近の値になるように保たれる。

【0085】そして、摩擦係数演算手段72は、最大摩擦力となるよう保持された制動力／駆動力をこの摩擦係数計測器の自重で除算して、接触面64における静止摩擦係数を計測する。これにより、接触面64の摩擦係数が連続的に変化する場合においても容易に静止摩擦係数を計測できる。

【0086】また、被計則面54が、例えば路面のように凹凸の多い場合、この計測器の自重に加えて余計な垂直方向の力が被計測面54にかかったり、逆に接触しなくなったりするため、演算される摩擦係数に大きな誤差が生じる。そこで、図6（A）及び（B）に示すように、タイヤ51の回転中心軸が上下に移動できるような軸取付けステー54を設けても良い。これにより、多少の凹凸のある場合でも、本実施例に係る摩擦計測装置は、被計測面54に常に自重でもって接触するので、正確な摩擦係数の測定が可能となる。なお、この場合、最大摩擦力の割数である自重は、タイヤ51とホイールモータ52の構成部分の荷重和であって、取付けステー53等の荷重は除外される。

【0087】また、本実施例に係る摩擦係数計測装置は単独でも利用できるが、取付けステー53を介して自動車等に第5輪として取り付ければ、自動車の制御にも応用できる。なお、この場合、タイヤ51と路面間の摩擦係数が、取り付けられた自動車のタイヤと路面間の摩擦係数と等しいか、或いは両摩擦係数間の一定の関係が予めわかっていることが必要である。

【0088】例えば、パワーステアリング装置に応用した場合、この装置により計測された路面摩擦係数と、走行中の横加速度に基づいて、旋回状態（横加速度）が限界状態になったときを判断し、このときにパワーステアリングの操舵力を通常時とは異なった大きさに変更する制御を行う。これによって、外乱が多く、路面の摩擦係数が刻々と変わる場合でも、摩擦係数計測装置により正確に摩擦係数を測定できるので、旋回状態の限界状態をより正確かつ安定に判断でき、安全性を向上させることができる。

【0089】さらに、アンチロックブレーキ制御にも応用することができる。この場合、車体側では、摩擦係数測定装置により測定された摩擦係数に基づいてタイヤと路面間の最大摩擦力を演算し、タイヤと路面間に働く力が演算された最大摩擦力となるように、ブレーキ力を制御する。或いは、この装置で演算した摩擦係数を直接渡すのでなく、摩擦状態演算手段70により演算された摩擦状態を車体の制御部に渡し、検出された摩擦状態が滑りだす直前になるようにブレーキ力を制御するようにしても良い。なお、後者の場合、摩擦係数計測装置のタイヤ51は、車体側のタイヤと同じ摩擦状態になるように制動を受けることが必要である。

【0090】以上が本発明に係る実施例であるが、上記例のみに限定されるものではない。例えば、上記第1実施例、第2実施例共に、加振力発生手段を用いて慣性体を振動系の共振周波数で微小加振するようにしていたが、応用分野によっては、加振力発生手段を用いない実施態様もあり得る。

【0091】第1の実施態様として、例えばホワイトノイズのような周波数特性を持つ外力が外乱として常に入力されている場合には、検出した振動成分から、共振周波数成分の実効値と全周波数成分の実効値とを求め、それらの比に基づいて共振特性を検出することができる。

【0092】また，第2の実施態様として、インパルス的又はステップ的な外力が頻繁に入力される場合には、この入力に対する応答波形から、共振周波数成分と、それ以外の周波数成分（若しくは全周波数成分）を分離し、それらの成分比から共振特性を求めることができる。

【0093】このように、第1の実施態様及び第2の実施態様は、加振力発生手段を用いないため、シンプルな構成となり、信頼性のみならず経済的にも有利になる。

【0094】また、共振特性として、共振ゲインや振動系の振幅値を演算したが、例えば、各摩擦状態に対応する振動系の共振周波数すべてを含む加振力で振動系を共振させ、最大振幅時の共振周波数の変化を演算するようにしても良い。

【００９５】さらに、加振力の周波数は、共振周波数と丁度一致しなくても、振動系の共振特性を明確に識別できる範囲であれば、共振周波数近傍の周波数でも良い。

【００９６】

【発明の効果】以上詳細に説明したように、請求項１及び請求項２の発明によれば、接触面の摩擦状態を、振動系の共振特性に基づいて演算するようにしたので、構成をシンプルにできると共に、外乱が多く、かつ、摩擦状態が時々刻々と変わるような場合でも、高い精度で正確に摩擦状態を検出することができる、という効果が得られる。

【００９７】請求項３及び請求項４の発明によれば、振動系の共振特性に基づいて演算された摩擦状態を、滑りだす直前の状態に維持することを可能としたので、滑ることが許されない場合などで、必要最小限の力により制御を円滑に実行することができる、という効果が得られる。

【００９８】請求項５の発明によれば、振動系の共振特性に基づいて摩擦係数を演算するようにしたので、構成をシンプルにできると共に、外乱が多く、かつ、摩擦状態が時々刻々と変わるような場合でも、高い精度で正確に摩擦係数を演算することができる、という効果が得られる。

【図面の簡単な説明】

【図１】本発明の第１実施例に係る荷物把持装置の外観図であり、（Ａ）は正面図、（Ｂ）は側面図を示す。

【図２】第１実施例に係る荷物把持装置の把持部の詳細な構成及び構成ブロック図である。

【図３】本発明の第２実施例に係る摩擦係数測定装置の外観図であり、（Ａ）は正面図、（Ｂ）は側面図を示す。

【図４】第２実施例に係る摩擦係数測定装置の回転軸換算したモデル及び構成ブロック図である。

【図５】制動力／駆動力のスリップ速度に対する特性を示す線図である。

【図６】第２実施例に係る摩擦係数測定装置の変形例であり、（Ａ）は正面図、（Ｂ）は側面図を示す。

【図７】外力と最大摩擦力との関係を示す図である。

【図８】共振特性を利用した摩擦状態検出の原理を説明するための振動系の等価モデルを示す図である。

【図９】タイヤと路面との間の摩擦係数μのスリップ率Ｓに対する特性を示す線図である。

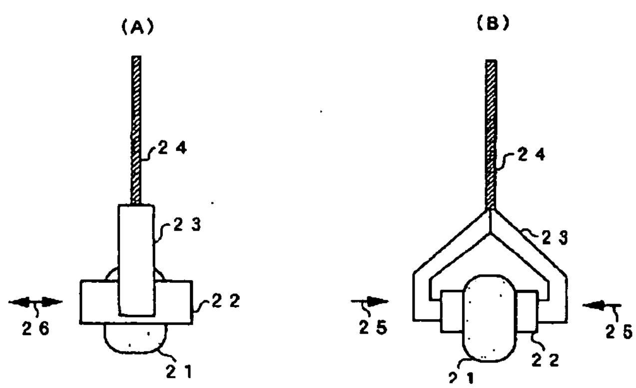
【図１０】車両の力学モデルを示す図である。

【図１１】車両の力学モデルを回転軸換算したモデルを示す図である。

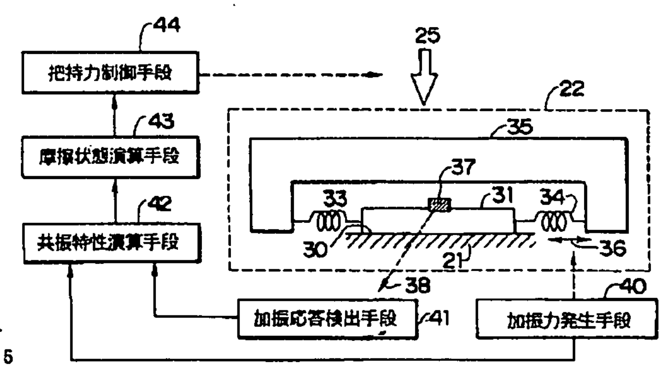
【符号の説明】

６７　加振力発生手段
６８　加振応答検出手段
６９　共振特性演算手段
７０　摩擦状態演算手段
７１　制動力／駆動力演算手段
７２　摩擦係数演算手段

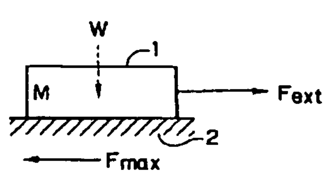
【図１】



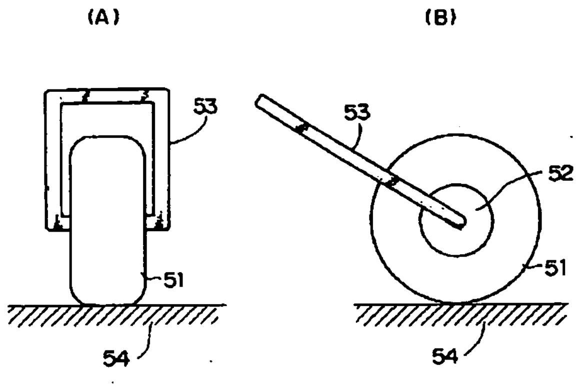
【図２】



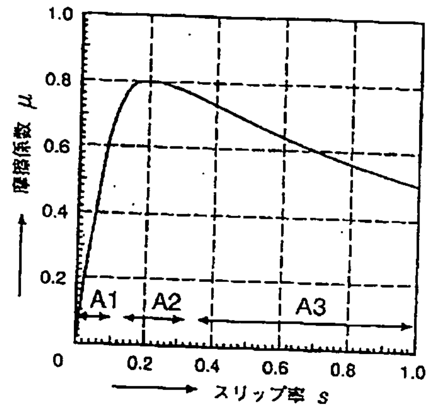
【図７】



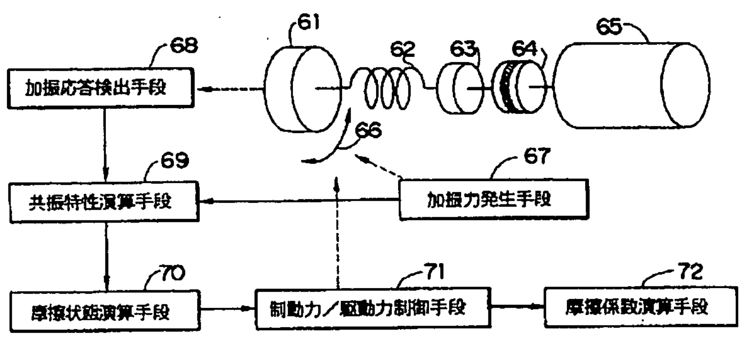
【図3】


(A)
(B)
53
52
51
54

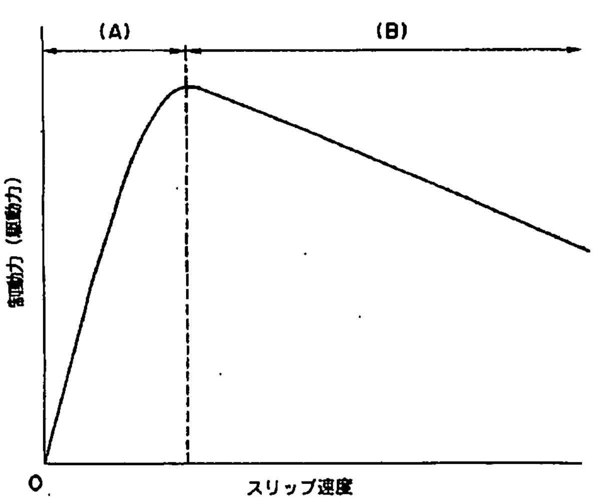
【図9】


1.0
0.8
0.6
0.4
0.2
0
摩擦係数 μ
A1
A2
A3
0.2
0.4
0.6
0.8
1.0
スリップ率 s

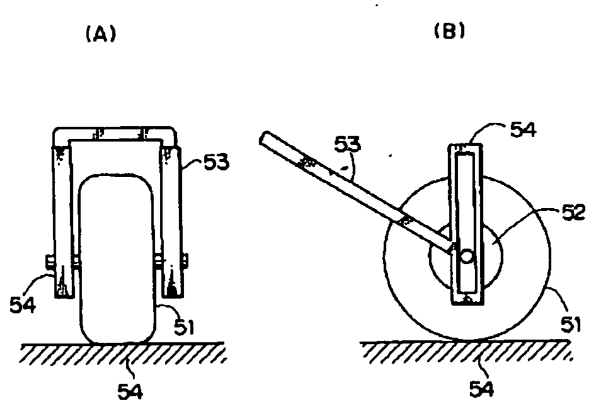
【図4】


61
62
63
64
65
66
67
68
69
70
71
72
加振応答検出手段
共振特性演算手段
加振力発生手段
摩擦状態演算手段
制動力／駆動力制御手段
摩擦係数演算手段

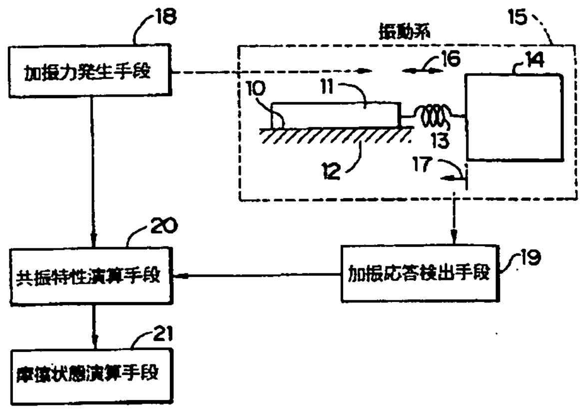
【図5】


(A)
(B)
制動力（駆動力）
0
スリップ速度

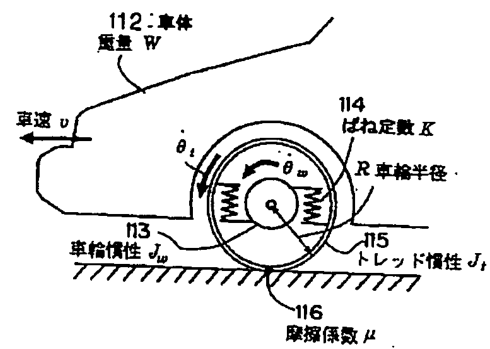
【図6】


(A)
(B)
53
54
51
52

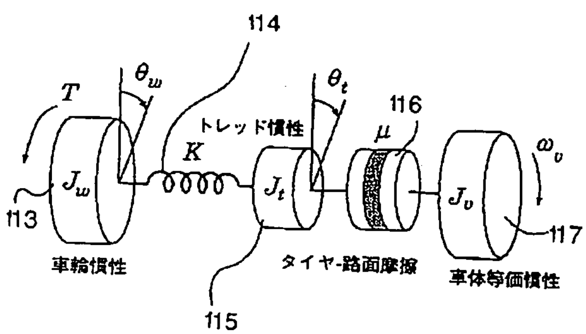
【図8】



【図10】



【図11】



フロントページの続き

(51)Int.Cl.⁶	識別記号	庁内整理番号	F I		技術表示箇所
G01N 3/56			G01N 3/56	G	
// B62D 137:00					

JAPANESE [JP,08-334454,A]

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE INVENTION TECHNICAL PROBLEM MEANS OPERATION EXAMPLE DESCRIPTION OF DRAWINGS DRAWINGS CORRECTION OR AMENDMENT

[Translation done.]

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CLAIMS

[Claim(s)]
[Claim 1] the one side side element of the contact surface which frictional force produces -- this contact surface and abbreviation -- vibration system which connected the spring element displaced in the parallel direction, and connected the inertial field to the other end of this spring element According to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency An exciting-force generating means to excite said vibration system, and an excitation response detection means to detect the quantity of state of the excitation response of vibration system by which excitation was carried out with this exciting-force generating means, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means, Friction condition detection equipment including a friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means.
[Claim 2] it connects with the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An external force detection means to detect the quantity of state of said external force, and a condition detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means, Friction condition detection equipment including a friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means.
[Claim 3] the one side side element of the contact surface which frictional force produces -- this contact surface and abbreviation -- vibration system which connected the spring element displaced in the parallel direction, and connected the inertial field to the other end of this spring element According to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency An exciting-force generating means to excite said vibration system in the generating direction of frictional force, and an excitation response detection means to detect the quantity of state of the excitation response of said vibration system by which excitation was carried out with this exciting-force generating means, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means, Friction condition detection equipment including a maximum-frictional-force state control means to control said applied force generating means to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to the one side side element of said contact surface, and said resonance characteristic operation means.
[Claim 4] it connects with the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An external force detection means to detect the quantity of state of said external force, and a condition detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means to calculate the resonance

characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means, Friction condition detection equipment including a maximum-frictional-force state control means to control said applied force generating means to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to the one side side element of said contact surface, and said resonance characteristic operation means.
[Claim 5] Friction condition detection equipment of claim 3 or claim 4 which includes further a maximum-frictional-force operation means to calculate the value of the maximum frictional force in said contact surface, and a coefficient-of-friction operation means to calculate coefficient of friction of said contact surface based on the value of the maximum frictional force calculated with this maximum-frictional-force operation means, based on the applied force when changing into a condition just before said contact surface starts with said maximum-frictional-force state control means.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the friction condition detection equipment controlled to be in a friction condition just before it detects a friction condition based on the resonance characteristic of the vibration system which has the contact surface which starts friction condition detection equipment, especially frictional force produces and the contact surface starts.
[0002]
[Description of the Prior Art] There is the following as the technique which measures frictional force or coefficient of friction, and a technique which controls by detecting a friction condition.
[0003] The maximum frictional force Fmax generated between the body 1 of mass M, and the measured field 2 in the model shown in drawing 7 It is Fmax =, when a load is set to W (=Mg;g is gravitational acceleration) and a coefficient of friction of rest is set to mustat. It is expressed with mustat-W. External force Fext impressed from the outside here Maximum frictional force Fmax If it is the following, it will stop at a quiescent state. However, external force Fext It is once the maximum frictional force Fmax. If it exceeds, it will start suddenly. The frictional force Ftran at that time is dynamic friction coefficient mutrans. Ftrans = It is expressed with mutrans and W.
[0004] However, it is external force Fext in this way. Maximum frictional force Fmax Since a condition changes a lot at the same time it is completely changeless and exceeded the maximum frictional force until it exceeded, it is very difficult to get to know whether it is in a condition just before starting before starting.
[0005] Then, in the conventional frictional force measuring device, it applies and lets external force slide in advance, and is the maximum frictional force Fmax at that time. By investigating, frictional force is measured and it is the maximum frictional force Fmax further. He was trying to measure coefficient-of-friction-of-rest mustat by doing a division by the self-weight of equipment.
[0006] Moreover, in the field of foundry technique, there is a technique which measures the frictional force which acts between a cast piece and mold on the occasion of the drawing of a cast piece performed connecting with the source of excitation through an excitation beam, making an excitation beam rock to the circumference of the predetermined supporting point by actuation of this source of excitation, and exciting this mold while carrying out fixed support of the mold for continuous casting at a shaking table. The frictional force between mold and a cast piece uses affecting the load of the source of excitation, and expresses the property of the vibration system of mold with a transfer function, and these techniques measure the frictional force between mold and a cast piece based on this transfer function. There is a technique indicated by JP,4-84652,A as a technique which expected improvement in operation speed, and accuracy especially with the frictional force measurement technique in the field of such foundry technique.
[0007] The technique of JP,4-84652,A calculates the frictional force which faces drawing out a cast piece from the mold by which excitation was carried out, and acts among both based on the rocking torque committed to mold in case the part of mold approach is excited according to the state space model formulized in the mode part solution method rather than the supporting point of an excitation beam, and the variation rate produced in mold by excitation. In addition, in order to search for the rocking torque committed to mold correctly, the approach of amending by distortion which detected distortion produced with an excitation beam in the part from the source of excitation rather than the supporting point of the exciting force which sources of excitation, such as an excitation cylinder, emit, and an excitation beam, and produced the detected exciting force with the excitation beam, and calculating rocking torque is used. Thus, in case a high-speed operation is attained and rocking torque is further calculated by making a model simple as a bending beam which excites the lumped mass which consists of a shaking table and mold the between to the mold which serves as an excitation object from the supporting point of an excitation beam with this technique by

the rocking torque which acts on the supporting point, measurement of exact frictional force is enabled by amending exciting force by distortion of an excitation beam.
[0008] Moreover, there is electronics control power-steering equipment indicated by JP,4-230472,A as a technique which measures coefficient of friction between a wheel and a road surface, and controls in the field of the control technique of an automobile based on this coefficient of friction.
[0009] The measuring method of coefficient of friction indicated by JP,4-230472,A A rear wheel by inputting an excitation signal into a solenoid valve from a controller A rudder angle equivalent to **1mm, **** periodically on the frequency of 2Hz and reaction force sensors, such as a load cell, detect the reaction force over the cornering force and self aryne GUTORUKU which were generated in the rear wheel by this periodic ****. A cornering power and selfer lining power are calculated based on the value of the detected reaction force, and road surface coefficient of friction is measured by the result of an operation based on the relation of these power and road surface coefficient of friction.
[0010] Moreover, even if it slams the brake by controlling a brake force so that it may be in a condition just before it guesses the friction condition of a road surface and a wheel and the contact surface starts, there is an anti-lock brake control unit as a technique which prevents locking a wheel and slipping.
[0011] Here, although a slip will arise between a wheel and a road surface if brakes are applied while running at a rate with a car, it is known that the coefficient of friction mu between a wheel and a road surface will change like drawing 9 to slip ratio S expressed with the following (1) type. In addition, vv* is vw whenever [real car-body-speed]. It is whenever [wheel speed].
[0012]
S=(vv*-vw)/vv* ... (1)
In this mu-S property, coefficient of friction mu comes to take peak value with a certain slip ratio (A2 field of drawing 9).
[0013] Then, he detects slip ratio from whenever [car-body-speed], and whenever [wheel speed], and was trying to control a brake force by the conventional anti-lock brake control unit to become the slip ratio to which coefficient of friction mu takes peak value.
[0014]
[Problem(s) to be Solved by the Invention] However, with the above-mentioned conventional frictional force detection equipment, when the case where sliding is not allowed, and coefficient of friction change, detecting on real time becomes very difficult about in what kind of condition a friction condition is now. There is load grasping equipment which grasps a load by the necessary minimum force which detects frictional force and a load does not slide down as such an example.
[0015] Moreover, in the frictional force measuring device of JP,4-84652,A, the linear model of the mold approximated with the lumped mass which is vibrating by rocking torque is assumed, and in order to calculate the frictional force which has affected vibration of mold only based on the variation rate of rocking torque and mold, there is a problem of being easy to be influenced of a noise etc. Moreover, under the conditions with which the above-mentioned assumption is not filled, in this model, since exact measurement of frictional force becomes impossible, the problem that the application range is very narrow arises. Even if it is able to build the model suitable for conditions, depending on a model, a complicated operation will be needed in many cases, and in this case, the new problem of it becoming impossible to calculate frictional force on real time is also produced.
[0016] Moreover, it is necessary to **** a wheel periodically, to generate a cornering force etc. and to detect the reaction force of the wheel to this, and there is a problem that a gaging system becomes complicated, by the measuring method of coefficient of friction indicated by JP,4-230472,A. Furthermore, since the relation between a cornering power etc. and road surface coefficient of friction is assumed with the predetermined model, the problem of being weak is also in a noise.
[0017] Moreover, in the conventional anti-lock brake control unit, the slip ratio from which the coefficient of friction mu between the tire under operation and a road surface changes every moment, and coefficient of friction mu serves as a peak since there are also many noises also changes, and suitable brake control becomes very difficult.
[0018] This invention was made in order to cancel the above-mentioned conventional trouble, and it assumes a model with the large dependence of a system configuration or conditions, and a friction condition is not detected based on a mere oscillation characteristic, a mere displacement response, etc. By making positively the resonance state which reflects frictional force more sensitively, and calculating a friction condition paying attention to the resonance characteristic of this resonance state While there are many noises and they can detect a friction condition correctly also in the situation that a friction condition changes every moment, it aims at offering the friction condition detection equipment of the large simple configuration of applicability.

[0019]
[Means for Solving the Problem] In order to attain the above-mentioned purpose, invention of claim 1 the one side side element of the contact surface which frictional force produces -- this contact surface and abbreviation -- according to the vibration system which connects the spring element displaced in the parallel direction, and comes to connect an inertial field with the other end of this spring element, and the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency An exciting-force generating means to excite said vibration system, and an excitation response detection means to detect the quantity of state of the excitation response of vibration system by which excitation was carried out with this exciting-force generating means, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means.
[0020] invention of claim 2 is connected to the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An external force detection means to detect the quantity of state of said external force, and a condition detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means.
[0021] the one side side element of the contact surface where frictional force produces invention of claim 3 -- this contact surface and abbreviation -- with the vibration system which connects the spring element displaced in the parallel direction, and comes to connect an inertial field with the other end of this spring element According to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency An exciting-force generating means to excite said vibration system in the generating direction of frictional force, and an excitation response detection means to detect the quantity of state of the excitation response of said vibration system by which excitation was carried out with this exciting-force generating means, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a maximum-frictional-force state control means to control said applied force generating means to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to the one side side element of said contact surface, and said resonance characteristic operation means.
[0022] invention of claim 4 is connected to the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An external force detection means to detect the quantity of state of said external force, and a condition detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a maximum-frictional-force state control means to control said applied force generating means to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to the one side side element of said contact surface, and said resonance characteristic operation means.
[0023] Invention of claim 5 is constituted based on the applied force when changing into a condition just before said contact surface starts with the maximum-frictional-force state control means of claim 3 or claim 4, including further a maximum-frictional-force operation means to calculate the value of the maximum frictional force in said contact surface, and a coefficient-of-friction operation means to calculate coefficient of friction of said contact surface based on the value of the maximum frictional force calculated with this maximum-frictional-force operation means.

[0024]
[Function] First, vibration system 15 of drawing 8 is used as a model, and the principle of this invention is explained. As shown in drawing 8 , vibration system 15 is mass Ma. An inertial field 11 and mass Mb which contacts through this inertial field 11 and contact surface 10 Mass Mc attached in the spring element 13 of spring constant K attached in the end of an inertial field 12 and an inertial field 11, and the other end of this spring element It consists of inertial fields 14.
[0025] since an inertial field 12 interlocks and vibration system 15 vibrates to vibration of an inertial field 11 in the condition that the contact surface 10 is not [the frictional force generated in the contact surface 10] slippery within the maximum frictional force -- the spring and mass Mc of mass (Ma+Mb) and spring constant K from -- it becomes becoming two systems of inertia and equivalence. Therefore, resonance frequency f1 in the vibration system 15 in case frictional force is less than the maximum frictional force f1 =root {(Ma+Mb+Mc) K/(Ma+Mb) Mc} /2pi ... (2)
It becomes. Moreover, if the inertial field 12 of another side is the fixed end, the resonance frequency f1 of (2) types is.
f1 =root (K/Mc) / 2pi ... (3)
It can be alike and can approximate.
[0026] since [on the other hand,] an inertial field 12 cannot be followed in footsteps of vibration of an inertial field 11 but the effect of the inertia becomes small, after frictional force has started exceeding the maximum frictional force -- vibration system 15 -- mass Ma Mass Mc from -- being equivalent to two becoming systems of inertia -- becoming -- the resonance frequency f2 f2 =root{(Ma+Mc) K/Ma Mc} / 2pi ... (4)
It becomes.
[0027] Here, it is resonance frequency f1 to a direction parallel to the contact surface 10 about this vibration system 15. Or the case where minute vibration is carried out by the exciting force 16 of an about [f1] frequency is assumed. the time of being in the condition that the contact surface 10 is not slippery -- the resonance frequency of vibration system 15 -- f1 it is -- since -- vibration system 15 -- setting -- frequency f1 An oscillating component is amplified. That is, vibration system 15 will be in the resonance state in which an about [frequency f1] oscillating component appears strongly. In addition, there is resonance gain expressed with a ratio with the maximum of the oscillating component of vibration system 15 to the maximum amplitude of exciting force 16 to express the resonance characteristic of vibration system 15. In the case of the resonance state, this resonance gain becomes larger to Haruka than 1, and when it is not the resonance state, it becomes small as compared with the resonance state.
[0028] On the other hand, if it comes until just before frictional force and the force of an opposite direction approach the maximum frictional force and start in the contact surface 10, phase contrast will begin to appear to vibration by exciting force 16, and vibration of an inertial field, and resonance gain will decrease rapidly.
[0029] And when the contact surface 10 shifts to the condition of sliding completely, the resonance frequency of vibration system 15 is f2. Frequency f1 given according to exciting force 16 since it was in agreement An oscillating component is decreased and vibration system 15 stops resonating.
[0030] Moreover, vibration system 15f2 When exciting by the exciting force 16 of a nearby frequency, and it is in the condition that the contact surface 10 is not slippery, and vibration system 15 does not resonate but the contact surface 10 starts, vibration system 15 is a frequency f2. An oscillating component will be in the resonance state which appears strongly.
[0031] Moreover, exciting force 16f1 f2 Although it resonates even when it is any in the condition of sliding with the condition that the contact surface 10 is not sliding on vibration system 15 when both the oscillating components of a nearby frequency are included, the resonance frequency from which the amplitude serves as a peak will change.
[0032] In addition, the model of vibration system with which an above-mentioned inertial field vibrates along with a straight line is easily extensible also to a rotational-vibration system. As shown in drawing 10 as a model of this rotational-vibration system, there is vibration system constituted by the oscillating phenomenon, i.e., the car body, wheel, and road surface in a wheel when the car equipped with the car body 112 of weight W is running at a rate v. Then, it explains with reference to the model which shows the oscillating phenomenon of this vibration system to drawing 11 modeled equivalent with the wheel revolving shaft.
[0033] Here, although a brake force (damping force) acts on a road surface through the front face of the tread 115 of the tire which touches a road surface, in order that this brake force may act on a car body 112 as reaction from a road surface in fact, the equivalence model 117 of revolving-shaft conversion of a body weight becomes what was connected with a wheel 113 and the opposite side through the friction element 116 between the tread of a tire, and a road surface. This is the same like chassis DYNAMO equipment with the ability of the weight of a car body to be simulated with the mass of the big inertia under a wheel, i.e., a wheel, and the opposite side.
[0034] It is [inertia / of the wheel 113 which contained the tire rim by drawing 10 and drawing 11] JV about the

inertia of the equivalence model 117 of K, and mu and revolving-shaft conversion of the weight of a car body 112 of the inertia of a tread 115 in the spring constant of the spring element 114 between Jw, a rim, and a tread 15. If it carries out, the property of the whole system will become like following (5) - (7). [coefficient of friction of the friction element 116 between Jt, a tread 115, and a road surface] In addition, the second degree differential d2 / dt2 below "" expresses the first degree differential d/dt about time amount, and concerning time amount It expresses with ""."

[0035]

JW thetaw" = -T+K (thetat-thetaw) ... (5)

Jt thetat" = -K(thetat-thetaw)+muWR ... (6)

Jv omegav' = -muWR ... (7)

It is here. ww = thetaw' ... (8)

Jv = R2 W ... (9)

omegav = v/r ... (10)

Come out, and it is and is thetaw. For the angle-of-rotation acceleration of a wheel 113, and ww, the angular rate of rotation of a wheel 113 and thetat are [the angle of rotation of a wheel 113, and thetaw"] the angle of rotation of a tread 115, and thetat". The angle-of-rotation acceleration of a tread 115, and omegav The weight of a car body and R of the angular rate of rotation of revolving-shaft conversion of the car-body equivalence model 117, the damping torque with which T is added to a wheel 113, and W are wheel radii. Braking-torque T is the pressure Pb of a brake bulb in fact. Control performs.

[0036] if it thinks that the tread 115 and the car-body equivalence model 117 are linked directly when the tire grips -- the inertia of the sum of the inertia of the car-body equivalence model 117, and the inertia of a tread 115, and the inertia of a wheel 113 -- resonating -- the resonance wave number f1 of the wheel resonance system at this time f1 =root {(Jw+Jt+Jv) K/Jw} (Jt+Jv) /2pi ... (11)

It becomes a next door, a formula (2), and the completely same format. This condition is a field A1 on drawing 9 . It corresponds.

[0037] When the coefficient of friction mu of a tire approaches Peak mu, the coefficient of friction mu on the front face of a tire stops being able to change easily to slip ratio S, and the component accompanying vibration of the inertia of a tread 115 stops on the contrary, influencing the car-body equivalence model 117. That is, a tread 115 and the car-body equivalence model 117 will be separated equivalent, and a tread 115 and a wheel 113 will cause resonance. Resonance frequency f2 of the wheel resonance system at this time f2 =root {(Jw+Jt) K/Jw Jt} /2pi ... (12)

It becomes a next door, a formula (4), and the completely same format. If this condition corresponds to the field A2 of drawing 9 and generally reaches the point of Peak mu, it changes to field A3 in an instant, and a tire locks it. On the other hand, the peak of the gain of whenever [in resonance frequency / wheel speed] also decreases rapidly just before Peak mu.

[0038] Size relation of each inertia Jt <Jw <Jv ... (13)

Come out, and it is and is this. f1 <f2 ... (14)

It comes to be alike. That is, when a tire results in a lock, the resonance frequency of a wheel resonance system will shift to a RF side. Moreover, change of this resonance frequency is rapidly generated near peak mu.

[0039] A model is simplified and it is the inertia Jt of a tread 115. If a peak mu condition is approached even when it ignores, change of the peak of the resonance frequency of a wheel resonance system and the gain of whenever [wheel speed] takes place, and the same analysis is possible for it.

[0040] As mentioned above, the resonance characteristic which frequency component [the existence of resonance of vibration system 15 or a wheel resonance system, change of resonance frequency, and] of exciting force amplified or declined by what resonance gain according to the friction condition of the contact surface changes a lot. On the contrary, if this resonance characteristic is detected, friction conditions (condition just before starting etc.), coefficient of friction, etc. of the contact surface can be calculated.

[0041] then, the one side side element of the contact surface which frictional force produces in invention of claim 1 -- this contact surface and abbreviation -- an exciting-force generating means excites the vibration system which connected the spring element displaced in the parallel direction, and connected the inertial field to the other end of this spring element according to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency. in addition, the variation rate of a spring element -- a direction -- the contact surface and abbreviation -- if it is an parallel direction (the inside of the contact surface is included) -- arbitration -- it can set up suitably. Next, an excitation response detection means detects the quantity of state of the excitation response of vibration system by which excitation was carried out. This excitation response is the acceleration of the inertial field by exciting force etc., and has frequency distribution of the oscillating component of acceleration

etc. as this quantity of state. Next, a resonance characteristic operation means calculates the resonance characteristic of said vibration system based on the quantity of state of exciting force, and the quantity of state of the detected excitation response. And a friction condition operation means calculates the friction condition in said contact surface based on the calculated resonance characteristic. According to this calculated friction condition, it can be identified and judged quantitatively whether it is in the condition that the contact surface is not slippery, a condition just before starting, and which condition in the condition of sliding. Moreover, since the resonance characteristic of vibration system is used, there is an advantage that detection sensitivity cannot be highly influenced easily of disturbance, such as a noise.
[0042] In calculating whether it is in a friction condition just before the contact surface 10 starts in the vibration system 15 of drawing 8 in this invention For example, resonance frequency f1 of the vibration system 15 when the contact surface 10 is not slippery Or f1 Vibration system 15 is excited on a nearby frequency. Frequency f1 The resonance gain of the vibrating component is calculated, and when this resonance gain becomes smaller than the 1st reference value, it judges with a condition just before a friction condition starts. Moreover, resonance frequency f2 when the contact surface is slippery It excites, and when the resonance gain of the component which vibrates on this frequency becomes larger than the 2nd reference value, you may judge with a condition just before starting. Furthermore, it is resonance frequency f1 at least. And f2 It may excite by the exciting force containing two oscillating components, and a friction condition may be calculated based on the value change of resonance frequency.
[0043] Moreover, when the external force which has frequency characteristics, such as white noise, in vibration system has always inputted, even if it does not give exciting force with an exciting-force generating means, vibration system vibrates by the resonance characteristic peculiar to a friction condition.
[0044] So, in invention of claim 2, an external force detection means detects the quantity of state of external force, and a response oscillating detection means detects the quantity of state of response vibration of the vibration system over external force. Next, a resonance characteristic operation means calculates the resonance characteristic based on the detected external force and the quantity of state of response vibration. And a friction condition operation means calculates the friction condition in the contact surface based on the calculated resonance characteristic. Thus, when vibration system causes resonance by external force, an exciting-force generating means can be omitted and equipment can be constituted simply.
[0045] Moreover, the principle of the friction condition detection based on the above resonance characteristics is applicable also to the equipment controlled to hold a condition, i.e., the maximum frictional force, just before the contact surface starts.
[0046] So, in invention of claim 3, an exciting-force generating means excites vibration system according to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency. Next, an excitation response detection means detects the quantity of state of the excitation response of vibration system by which excitation was carried out, and a resonance characteristic operation means calculates the resonance characteristic of vibration system based on the quantity of state of exciting force, and the quantity of state of the detected excitation response. Moreover, applied force is given to the one side side element of the contact surface by the applied force generating means, and this applied force is controlled by the maximum-frictional-force state control means to be in a condition just before the contact surface starts based on the calculated resonance characteristic. This grasps a load, and since the retention span (applied force) which grasps a load with the equipment to which lift up and it is made to move is controlled to be in a friction condition just before the contact surface with a load starts, a possibility of destroying a load superfluously at a big retention span is avoidable. In addition, there is damping force like a brake force which acts on the driving force for rotating a wheel etc. other than a retention span, a wheel, etc. as a mode of this applied force. If a brake force is controlled to be in a condition just before the friction condition of a wheel and a road surface starts, it is applicable also to an anti-lock brake control unit.
[0047] Moreover, when the external force which has frequency characteristics, such as white noise, in vibration system like invention of claim 2 has always inputted, even if it does not give exciting force with an exciting-force generating means, vibration system vibrates by the resonance characteristic peculiar to a friction condition.
[0048] So, in invention of claim 4, an external force detection means detects the quantity of state of external force, and a response oscillating detection means detects the quantity of state of response vibration of the vibration system over external force. Next, a resonance characteristic operation means calculates the resonance characteristic based on the detected external force and the quantity of state of response vibration. Moreover, applied force is given to the one side side element of the contact surface by the applied force generating means, and this applied force is controlled by the maximum-frictional-force state control means to be in a condition just before the contact surface starts based on the calculated resonance characteristic. Thus, when vibration system causes resonance by external force, an exciting-force generating means can be omitted and equipment can be constituted simply.

[0049] Moreover, when applied force is controlled to be held like invention of claim 3 or claim 4 at a condition just before the contact surface starts, the force generated in the contact surface according to this applied force turns into force equal to the maximum frictional force. Therefore, the value of the maximum frictional force can be calculated based on applied force. Furthermore, if the value of the maximum frictional force is known, a coefficient of friction of rest will be called for by doing the division of this by the self-weight of equipment.
[0050] So, in invention of claim 5, the value of the maximum frictional force in the contact surface is calculated with a maximum-frictional-force operation means based on the applied force when changing into a condition just before the contact surface starts. And based on the value of the calculated maximum frictional force, a coefficient of friction of rest is calculated with a coefficient-of-friction operation means. Even when coefficient of friction measures by this on the road surface which changes every moment, a coefficient of friction of rest can be detected correctly and continuously.
[0051]
[Example]
(The 1st example) The example of the friction condition detection equipment using the resonance characteristic is hereafter explained to a detail based on a drawing.
[0052] The 1st example explained below makes it possible to grasp by the suitable force, without [without it drops a load by applying to the load grasping equipment to which a load is grasped and the friction condition detection equipment of this invention is moved like a crane, and] damaging a load. The load grasping equipment concerning this 1st example is explained referring to drawing 1 and drawing 2 .
[0053] As shown in the front view of drawing 1 (A), the load grasping equipment concerning this example consists of pulling devices (with no illustration) for leading the wire 24 attached in this retention span generating section 23, and this wire 24, in order to lift the retention span generating section 23 for giving a retention span to the grasping section 22 which grasps a load 21, and this grasping section 22, and the whole. Moreover, when the appearance of this load grasping equipment is seen from a side face, it turns out that it is shown like drawing 1 (B) and the retention span 25 which grasps a load 21 is given in the direction which drawing shows.
[0054] In addition, the maximum frictional force generated in the contact surface of the grasping section 22 and a load 21 is determined by the product of coefficient-of-friction-of-rest mustat in a retention span 25 and this contact surface. Therefore, when a retention span 25 is large enough and the maximum frictional force is beyond the load of a load 21, a load 21 is not slid down, but when a retention span becomes small and the maximum frictional force becomes smaller than the load of a load 21, a load 21 will be slid down conversely.
[0055] The control system for controlling a retention span 25 to drawing 2 and the detailed configuration of the grasping section 22 are shown. It is the mass Mc from which the grasping section 22 constitutes that outline part as shown in drawing 2 . The spring element 33 and the spring element 34 of spring constant K / 2 are minded [this / 35] respectively, and it is [an inertial field 35 and] mass Mb. Mass Ma attached in the side in contact with a load 21 It is constituted including the contact section 31.
[0056] In addition, the contact section 31 is attached so that it may displace horizontally through the spring element 33 and the spring element 34. That is, in this example, the displacement directions of a spring element are the contact surface 30 and abbreviation parallel, and the generating direction of the frictional force which resists the load of a load 21 becomes perpendicular.
[0057] Moreover, between the contact section 31 and an inertial field 35, the exciting-force generating means 40 which applies and carries out the minute excitation of the exciting force 36 of the excitation frequency f2 (=root {(Ma+Mc) K/MaMc} /2pi) is attached in the direction in which the spring element 33 and the spring element 34 displace the contact section 31. As shown in drawing 1 (A), minute vibration of the load 21 will be carried out to a horizontal direction 26 with the contact section 31 according to this exciting force 36. This exciting-force generating means 40 attaches a piezoelectric device in the anchoring parts of the spring element 33 and the spring element 34, and can realize it easily by carrying out the variation rate of this piezoelectric device with an electric drive. Moreover, the magnetic substance and a coil are attached in the contact section 31 and an inertial field 35, respectively, and it can realize easily also by carrying out minute excitation by the suction repulsive force of an electromagnet.
[0058] Furthermore, an excitation response detection means 41 to detect the response characteristic of the contact section 31 at the time of minute excitation being carried out by the exciting-force generating means 40 is attached in the contact section 31. This response detection means 41 is realizable with the accelerometer 37 which measures the acceleration 38 of the contact section 31 by exciting force 36 as a response characteristic.
[0059] Moreover, a resonance characteristic operation means 42 to calculate the resonance characteristic of the grasping section 22 which grasped the load 21 based on response characteristics, such as the exciting force 36 given by

the exciting-force generating means 40 and the acceleration 38 detected by the excitation response detection means 41, is established. This resonance characteristic is expressed with the ratio (resonance gain) of the maximum amplitude of the oscillating component of acceleration 38 to the maximum amplitude of exciting force 36, change of resonance frequency, etc.

[0060] Furthermore, based on a friction condition operation means 43 to judge the friction condition of the contact surface of the contact section 31 and a load 21 based on the resonance characteristic calculated with the resonance characteristic operation means 42, and this judged friction condition, the retention span control means 44 which adjusts the retention span which controls the retention span generating section 23 and is impressed to the grasping section 22 the optimal is established.

[0061] Next, an operation of this load grasping equipment is explained. Excitation frequency f2 of the exciting force given by the exciting-force generating means 40 It is the resonance frequency of the vibration system which consists of the contact section 31 when the contact section 31 is separated with the load 21, the spring element 33, the spring element 34, and an inertial field 35.

[0062] By the way, when the load 21 is firmly grasped by the retention span 25 of the grasping section 22 Since a load 21 follows in footsteps completely and vibrates with minute vibration of the contact section 31 by exciting force 36, this vibration system Mass Ma It is the mass Mb of a load 21 to the contact section 31. It becomes equivalent to the added vibration system, and resonance frequency is set to f1 (=root {(Ma+Mb+Mc) K/(Ma+Mb) Mc} /2pi). For this reason, when the load 21 is grasped firmly, it is the excitation frequency f2. In exciting force, this vibration system does not resonate but the acceleration 38 detected by the excitation response detection means 41 and the resonance gain calculated with the resonance characteristic operation means 42 serve as a small value as compared with the case where it resonates.

[0063] On the other hand, if the retention span 25 of the grasping section 22 becomes weaker gradually and the maximum frictional force in the contact surface 30 becomes small below at a fixed value, a load 21 cannot be followed in footsteps of minute vibration of the contact section 31 by exciting force 36, but it is mass Mb. Since effect becomes small, the resonance frequency of vibration system is f2. It approaches. Therefore, frequency f2 of the acceleration 38 detected by the excitation response detection means 41 The oscillating component is amplified and, thereby, resonance gain also increases it gradually. If it becomes just before a load 21 starts especially, the excitation frequency component of acceleration will increase rapidly.

[0064] If resonance gain calculates with the resonance characteristic operation means 42, the friction condition operation means 43 will calculate the friction condition in the contact surface 30 based on this resonance gain. For example, the friction condition which is about the friction condition which is in the condition of not sliding when resonance gain is smaller than a reference value just before starting when resonance gain is beyond a reference value is calculated. With the operation value which shows this friction condition, in any in the condition of not sliding, a condition just before starting, and the condition of having started the condition of the contact surface 30 is can carry out a discernment judging. In addition, in the case of this example, this friction condition operation means 43 is also good to judge whether it became, just before only starting.

[0065] And based on the calculated friction condition, the retention span control means 44 controls the retention span generating section 23 so that a retention span 25 is maintained at a necessary minimum value. That is, since the load 21 is grasped firmly, to the case in the friction condition of not sliding, it controls to decrease a retention span 25, and controls to it to make a retention span 25 increase in the case of the friction condition judged just before starting. In addition, it is made to transmit the resonance characteristics, such as resonance gain calculated with the resonance characteristic operation means 42, to the retention span control means 44, and you may make it control a retention span 25 directly based on the value of the resonance characteristic. In this case, the friction condition operation means 43 becomes unnecessary.

[0066] Since a friction condition is correctly [continuously and] detectable as mentioned above, it becomes possible to control to a necessary minimum retention span just before a load starts. It also becomes possible for this to avoid breakage of the load by the large retention span beyond the need. Moreover, since the property to change the resonance frequency of vibration system sharply according to a friction condition is used, detection sensitivity cannot be highly influenced easily of disturbance. Furthermore, a control system can also be constituted simply and cheaply and has the advantage of being reliable.

[0067] (The 2nd example) The principle of the friction condition detection using the resonance characteristic is applicable also to the coefficient-of-friction metering device which measures coefficient of friction. It explains referring to drawing 3 and drawing 4 as a coefficient-of-friction metering device applied to the 2nd example in this.

[0068] As shown in the front view of drawing 3 (A), this friction condition metering device is constituted including the

anchoring stay 53 and the control system which is not illustrated for supporting the tire 51 which contacts that it is also by the self-weight of this metering device to the measured field 54 (road surface), and this tire 51. This anchoring stay 53 is attached in the equipment using coefficient of friction measured by this metering device, for example, a car body etc., (with no illustration). Below, the anchoring stay 53 assumes the case where it is attached in the car body.

[0069] Moreover, as shown in the side elevation of drawing 3 (B), the wheel side of a tire 51 is equipped with the wheel motor 52 made to rotate a tire 51.

[0070] Here, the equivalence model of the vibration system which consists of the configurations and this metering device and the measured field 54, and car bodies of the whole control system of the coefficient-of-friction metering device constituted like drawing 3 is shown in drawing 4 . According to drawing 4 , the control system of the coefficient-of-friction metering device of drawing 3 Moment of inertia Mc The oscillating component of the rotational speed of the wheel motor 52 by which it was superimposed on an exciting-force generating means 67 to make the minute oscillating component of resonance frequency f1 (=root(K/Mc) /2pi) superimpose on the torque command of the wheel motor 52, and the minute oscillating component is detected. The resonance characteristic A resonance characteristic operation means 69 to calculate, So that the damping force/driving force to the wheel motor 52 may serve as maximum based on a friction condition operation means 70 to judge the friction condition of a tire 51 and the measured field 54 based on the detected resonance characteristic, and the judged friction condition It is constituted including the damping force / driving force control means 71 to control, and a coefficient-of-friction operation means 72 to measure the coefficient of friction of rest of the contact surface by doing the division of damping force/the driving force by the self-weight of this measuring instrument.

[0071] Moreover, each element of the equivalence model of the vibration system shown in drawing 4 is equivalent to the following element in drawing 3 respectively. An inertial field 61 is moment of inertia Mc. For the rotator of the wheel motor 52, and the spring element 62, if spring constant K of the tire sidewall of a tire 51 twists, an inertial field 63 will be moment of inertia Ma. It is respectively equivalent to the belt section of a tire 51. Moreover, the contact surface 64 is the equivalence moment of inertia Mb on the same axle about the inertia of the car body in which it was equivalent to the contact surface of a tire 51 and the measured field 54, and the inertial field 65 attached in with the stator section of the wheel motor 52, and stay 53 and this measuring instrument were attached. It expresses by carrying out. In addition, since the resonance characteristic depending on the friction condition of the contact surface 64 in the equivalence model of drawing 4 follows the completely same principle as the equivalence model of drawing 11 mentioned above, it omits detailed explanation.

[0072] Next, an operation of the coefficient-of-friction metering device concerning this example is explained with reference to the equivalence model of drawing 4 .

[0073] The case where it is rolling without a tire 51 sliding on the measured field 54 first is assumed. in this case, this metering device, the measured field 54, and the vibration system that consists of car bodies -- moment of inertia (Ma+Mb) and moment of inertia Mc from -- two becoming systems of inertia are resembled and that resonance frequency is set to f1 (=root {(Ma+Mb+Mc) K/(Ma+Mb) Mc} /2pi).

[0074] Here, it is f1 = when >(Ma+Mb) >Mc is taken into consideration. root (K/Mc) / 2pi can be resembled.

[0075] The exciting-force generating means 67 makes the minute oscillating component of a frequency f1 (root (K/Mc) /2pi) superimpose on the torque command to the wheel motor 52. Therefore, in the inertial field 61 equivalent to the rotator of the wheel motor 52, it is a frequency f1. The vibrating excitation torque 66 starts. When it is in the condition that the contact surface is not slippery, it is the resonance frequency f1 of this vibration system. The frequency of the excitation torque 66 is in agreement, and vibration system resonates.

[0076] Next, the excitation response detection means 68 detects the oscillating component of the rotational speed of the inertial field 61 produced by the excitation torque 66. When it is in the condition that the contact surface is not slippery as mentioned above, it is resonance frequency f1 by this excitation response detection means 68. A big rotational-speed oscillating component is detected.

[0077] Next, the resonance characteristic operation means 69 is resonance frequency f1 as the resonance characteristic. The amplitude value of an oscillating component is calculated. This is effective when the maximum amplitude of the excitation torque 66 always takes constant value. In addition, you may ask for a ratio (resonance gain) with the maximum of the oscillating component of rotational speed to the maximum amplitude of the excitation torque 66 like the 1st example.

[0078] And the friction condition operation means 70 calculates the friction condition of the contact surface based on the resonance characteristic. For example, the friction condition which started the friction condition which is in the condition of not sliding when amplitude value exceeds a reference value when amplitude value was smaller than a reference value is calculated. In addition, since the big rotational-speed oscillating component has appeared in this case,

it is judged with not sliding on the contact surface according to the calculated friction condition.
[0079] Next, damping force / driving force control means 71 controls the damping force/driving force which acts on the measured field 54 through a tire 51 to be in a friction condition just before the contact surface is slippery based on the calculated friction condition. That is, a brake force which suppresses rotation of a tire 51 when attached in the car body which is running at the rate with this equipment is given as damping force, and it is attached in equipment without driving force, or conversely, in being independent, it gives the driving force for rotating a tire 51 by the wheel motor 52. In addition, if driving force is made to increase, a big load may be covered over this metering device so that the frictional force which resists this may increase immediately to the maximum frictional force.
[0080] When judged with the condition that the contact surface is not slippery as mentioned above, damping force / driving force control means 71 is controlled to make damping force/driving force increase. Thereby, the frictional force which resists damping force/driving force increases.
[0081] Here, the relation between the damping force/driving force to slip velocity (relative velocity of the tread of a tire 51 and the measured field 54) is shown to drawing 5 . In drawing 5 , the range of the slip velocity of this field (A) supports the condition that the contact surface 64 is not slippery. Drawing shows that damping force/driving force is increasing with the increment in slip velocity in a field (A). In addition, slip velocity becomes larger than 0 in the field (A) on which it originally should not be sliding for the tread itself carrying out elastic deformation, after the tread of a tire 51 grounds before separating, and although it is not sliding on the contact surface 64, it is because it is visible as if it was sliding when it sees by the relation between whenever [car-body-speed] and the rotational speed of a tire 51.
[0082] Thus, when judged with the contact surface not being slippery, damping force/driving force increases, but if this force comes to exceed the maximum frictional force, the contact surface 64 will actually come to start. In drawing 5 , the field (B) after damping force/driving force reached the peak is equivalent to the condition that the contact surface 64 actually starts.
[0083] if the contact surface starts -- an inertial field 65 -- frequency f1 vibration -- it cannot follow in footsteps -- that moment of inertia Mb since effect becomes small -- this vibration system -- moment of inertia Ma Moment of inertia Mc from -- two becoming systems of inertia are resembled and resonance frequency is set to f2 (=root {(Ma+Mc) K/Ma Mc} /2pi). From this, the exciting-force generating means 67 is a frequency f1. Even if it carries out minute excitation with the excitation torque 66, vibration system does not resonate, but the oscillating component of the rotational speed detected by the excitation response detection means 68 becomes small. And if the maximum amplitude value calculated with the resonance characteristic operation means 69 decreases and it becomes below a reference value, the friction condition operation means 70 will calculate the friction condition in the condition that the contact surface is slippery. Based on this friction condition, damping force / driving force control means 71 is controlled so that damping force/driving force decreases. In the example of drawing 5 , it turns out that damping force/driving force decreases with the increment in slip velocity in a field (B).
[0084] As mentioned above, it is held at a condition just before the friction condition of the contact surface is slippery by controlling to make damping force/driving force increase, when it judges with the contact surface 64 not being slippery, and controlling to decrease damping force/driving force, when it judges with the contact surface 64 being slippery. That is, the value (it corresponds to the peak of drawing 7) of the force applied to the tread of a tire with damping force/driving force is maintained so that it may become a value near [in the contact surface 64] the maximum frictional force.
[0085] And the coefficient-of-friction operation means 72 does the division of the damping force/the driving force held so that it might become the maximum frictional force by the self-weight of this coefficient-of-friction measuring instrument, and measures the coefficient of friction of rest in the contact surface 64. Thereby, when coefficient of friction of the contact surface 64 changes continuously, a coefficient of friction of rest can be measured easily.
[0086] Moreover, since the force of an excessive perpendicular direction is not applied to the measured field 54 or ****** 54-ed stops contacting conversely like a road surface in addition to the self-weight of this measuring instrument when there is much irregularity, gross errors arise in coefficient of friction to calculate. Then, as shown in drawing 6 (A) and (B), the axial anchoring stay 54 which the center-of-rotation shaft of a tire 51 can move up and down may be formed. Thereby, when there is some irregularity, or since the friction metering device concerning this example always contacts the measured field 54 as it is also by self-weight, the measurement of exact coefficient of friction of it is attained. In addition, in this case, the self-weight which is the number of rates of the maximum frictional force is the load sum of a tire 51 and the component of the wheel motor 52, and the load of anchoring stay 53 grade is excepted.
[0087] Moreover, even if the coefficient-of-friction metering device concerning this example is independent, it can use, but if it attaches in an automobile etc. as the 5th flower through the anchoring stay 53, it is applicable also to control of an automobile. In addition, it is required to be equal to a tire 51, the tire of the automobile in which coefficient of

friction between road surfaces was attached, and coefficient of friction between road surfaces, or to know beforehand the fixed relation between both coefficient of friction in this case.

[0088] For example, when it applies to power-steering equipment, based on the lateral acceleration under transit, the time of a revolution condition (lateral acceleration) turning into the critical state is judged to be road surface coefficient of friction measured by this equipment, and control which changes the control force of power steering into usually different magnitude from the time at this time is performed. By this, there can be much disturbance, since coefficient of friction can be correctly measured with a coefficient-of-friction metering device even when coefficient of friction of a road surface changes every moment, the critical state of a revolution condition can be judged to more exact and stability, and safety can be raised.

[0089] Furthermore, it is applicable also to anti-lock brake control. In this case, based on coefficient of friction measured by the coefficient-of-friction measuring device, the maximum frictional force between a tire and a road surface is calculated, and a brake force is controlled by the car-body side to become a tire and the maximum frictional force which the force committed between road surfaces calculated. Or coefficient of friction calculated with this equipment is not passed directly, but you may make it control a brake force to become, just before delivery and the detected friction condition start the friction condition calculated with the friction condition operation means 70 in the control section of a car body. In addition, in the case of the latter, the tire 51 of a coefficient-of-friction metering device needs to receive braking so that it may be in the same friction condition as the tire by the side of a car body.

[0090] Although the above is an example concerning this invention, it is not limited only to the above-mentioned example. For example, although the 1st example of the above and the 2nd example are made to carry out the minute excitation of the inertial field with the resonance frequency of vibration system using an exciting-force generating means, they may also have the embodiment which does not use an exciting-force generating means depending on an applicable field.

[0091] When the external force which has frequency characteristics like white noise as the 1st embodiment is always inputted as disturbance, the actual value of an oscillating component to a resonance frequency component and the actual value of a perimeter wave number component which were detected can be calculated, and the resonance characteristic can be detected based on those ratios.

[0092] Moreover, when the impulse-or step-external force as the 2nd embodiment is inputted frequently, a resonance frequency component and the other frequency component (or perimeter wave number component) can be separated from the response waveform to this input, and the resonance characteristic can be searched for from those component ratios.

[0093] Thus, since an exciting-force generating means is not used for the 1st embodiment and 2nd embodiment, they serve as a simple configuration and become economically and advantageous only not only in dependability.

[0094] Moreover, although the amplitude value of resonance gain or vibration system was calculated, vibration system is resonated by the exciting force containing all the resonance frequency of the vibration system corresponding to each friction condition, and you may make it calculate change of the resonance frequency at the time of maximum amplitude as the resonance characteristic, for example.

[0095] Furthermore, even if the frequency of exciting force is not in agreement with resonance frequency exactly, as long as it is the range which can identify the resonance characteristic of vibration system clearly, the frequency near the resonance frequency is sufficient as it.

[0096]

[Effect of the Invention] According to invention of claim 1 and claim 2, since the friction condition of the contact surface was calculated based on the resonance characteristic of vibration system, while being able to make a configuration simple, there is much disturbance, and as explained to the detail above, even when a friction condition changes every moment, the effectiveness that a friction condition is correctly detectable in a high precision is acquired.

[0097] Since it made it possible to maintain the friction condition calculated based on the resonance characteristic of vibration system in the condition just before starting according to invention of claim 3 and claim 4, the effectiveness that control can be smoothly performed according to the necessary minimum force is acquired by the case where sliding is not allowed etc.

[0098] Since coefficient of friction was calculated based on the resonance characteristic of vibration system, while being able to make a configuration simple according to invention of claim 5, there is much disturbance, and even when a friction condition changes every moment, the effectiveness that coefficient of friction can be correctly calculated in a high precision is acquired.

[Translation done.]

TECHNICAL FIELD

[Industrial Application] This invention relates to the friction condition detection equipment controlled to be in a friction condition just before it detects a friction condition based on the resonance characteristic of the vibration system which has the contact surface which starts friction condition detection equipment, especially frictional force produces and the contact surface starts.

[Translation done.]

PRIOR ART

[Description of the Prior Art] There is the following as the technique which measures frictional force or coefficient of friction, and a technique which controls by detecting a friction condition.
[0003] The maximum frictional force Fmax generated between the body 1 of mass M, and the measured field 2 in the model shown in drawing 7 It is Fmax =, when a load is set to W (=Mg;g is gravitational acceleration) and a coefficient of friction of rest is set to mustat. It is expressed with mustat-W. External force Fext impressed from the outside here Maximum frictional force Fmax If it is the following, it will stop at a quiescent state. However, external force Fext It is once the maximum frictional force Fmax. If it exceeds, it will start suddenly. The frictional force Ftran at that time is dynamic friction coefficient mutrans. Ftrans = It is expressed with mutrans and W.
[0004] However, it is external force Fext in this way. Maximum frictional force Fmax Since a condition changes a lot at the same time it is completely changeless and exceeded the maximum frictional force until it exceeded, it is very difficult to get to know whether it is in a condition just before starting before starting.
[0005] Then, in the conventional frictional force measuring device, it applies and lets external force slide in advance, and is the maximum frictional force Fmax at that time. By investigating, frictional force is measured and it is the maximum frictional force Fmax further. He was trying to measure coefficient-of-friction-of-rest mustat by doing a division by the self-weight of equipment.
[0006] Moreover, in the field of foundry technique, there is a technique which measures the frictional force which acts between a cast piece and mold on the occasion of the drawing of a cast piece performed connecting with the source of excitation through an excitation beam, making an excitation beam rock to the circumference of the predetermined supporting point by actuation of this source of excitation, and exciting this mold while carrying out fixed support of the mold for continuous casting at a shaking table. The frictional force between mold and a cast piece uses affecting the load of the source of excitation, and expresses the property of the vibration system of mold with a transfer function, and these techniques measure the frictional force between mold and a cast piece based on this transfer function. There is a technique indicated by JP,4-84652,A as a technique which expected improvement in operation speed, and accuracy especially with the frictional force measurement technique in the field of such foundry technique.
[0007] The technique of JP,4-84652,A calculates the frictional force which faces drawing out a cast piece from the mold by which excitation was carried out, and acts among both based on the rocking torque committed to mold in case the part of mold approach is excited according to the state space model formulized in the mode part solution method rather than the supporting point of an excitation beam, and the variation rate produced in mold by excitation. In addition, in order to search for the rocking torque committed to mold correctly, the approach of amending by distortion which detected distortion produced with an excitation beam in the part from the source of excitation rather than the supporting point of the exciting force which sources of excitation, such as an excitation cylinder, emit, and an excitation beam, and produced the detected exciting force with the excitation beam, and calculating rocking torque is used. Thus, in case a high-speed operation is attained and rocking torque is further calculated by making a model simple as a bending beam which excites the lumped mass which consists of a shaking table and mold the between to the mold which serves as an excitation object from the supporting point of an excitation beam with this technique by the rocking torque which acts on the supporting point, measurement of exact frictional force is enabled by amending exciting force by distortion of an excitation beam.
[0008] Moreover, there is electronics control power-steering equipment indicated by JP,4-230472,A as a technique which measures coefficient of friction between a wheel and a road surface, and controls in the field of the control technique of an automobile based on this coefficient of friction.
[0009] The measuring method of coefficient of friction indicated by JP,4-230472,A A rear wheel by inputting an excitation signal into a solenoid valve from a controller A rudder angle equivalent to **1mm, **** periodically on the

frequency of 2Hz and reaction force sensors, such as a load cell, detect the reaction force over the cornering force and self aryne GUTORUKU which were generated in the rear wheel by this periodic ****. A cornering power and selfer lining power are calculated based on the value of the detected reaction force, and road surface coefficient of friction is measured by the result of an operation based on the relation of these power and road surface coefficient of friction.

[0010] Moreover, even if it slams the brake by controlling a brake force so that it may be in a condition just before it guesses the friction condition of a road surface and a wheel and the contact surface starts, there is an anti-lock brake control unit as a technique which prevents locking a wheel and slipping.

[0011] Here, although a slip will arise between a wheel and a road surface if brakes are applied while running at a rate with a car, it is known that the coefficient of friction mu between a wheel and a road surface will change like drawing 9 to slip ratio S expressed with the following (1) type. In addition, vv* is vw whenever [real car-body-speed]. It is whenever [wheel speed].

[0012]

S=(vv*-vw)/vv* ... (1)

In this mu-S property, coefficient of friction mu comes to take peak value with a certain slip ratio (A2 field of drawing 9).

[0013] Then, he detects slip ratio from whenever [car-body-speed], and whenever [wheel speed], and was trying to control a brake force by the conventional anti-lock brake control unit to become the slip ratio to which coefficient of friction mu takes peak value.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] According to invention of claim 1 and claim 2, since the friction condition of the contact surface was calculated based on the resonance characteristic of vibration system, while being able to make a configuration simple, there is much disturbance, and as explained to the detail above, even when a friction condition changes every moment, the effectiveness that a friction condition is correctly detectable in a high precision is acquired.
[0097] Since it made it possible to maintain the friction condition calculated based on the resonance characteristic of vibration system in the condition just before starting according to invention of claim 3 and claim 4, the effectiveness that control can be smoothly performed according to the necessary minimum force is acquired by the case where sliding is not allowed etc.
[0098] Since coefficient of friction was calculated based on the resonance characteristic of vibration system, while being able to make a configuration simple according to invention of claim 5, there is much disturbance, and even when a friction condition changes every moment, the effectiveness that coefficient of friction can be correctly calculated in a high precision is acquired.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, with the above-mentioned conventional frictional force detection equipment, when the case where sliding is not allowed, and coefficient of friction change, detecting on real time becomes very difficult about in what kind of condition a friction condition is now. There is load grasping equipment which grasps a load by the necessary minimum force which detects frictional force and a load does not slide down as such an example.
[0015] Moreover, in the frictional force measuring device of JP,4-84652,A, the linear model of the mold approximated with the lumped mass which is vibrating by rocking torque is assumed, and in order to calculate the frictional force which has affected vibration of mold only based on the variation rate of rocking torque and mold, there is a problem of being easy to be influenced of a noise etc. Moreover, under the conditions with which the above-mentioned assumption is not filled, in this model, since exact measurement of frictional force becomes impossible, the problem that the application range is very narrow arises. Even if it is able to build the model suitable for conditions, depending on a model, a complicated operation will be needed in many cases, and in this case, the new problem of it becoming impossible to calculate frictional force on real time is also produced.
[0016] Moreover, it is necessary to **** a wheel periodically, to generate a cornering force etc. and to detect the reaction force of the wheel to this, and there is a problem that a gaging system becomes complicated, by the measuring method of coefficient of friction indicated by JP,4-230472,A. Furthermore, since the relation between a cornering power etc. and road surface coefficient of friction is assumed with the predetermined model, the problem of being weak is also in a noise.
[0017] Moreover, in the conventional anti-lock brake control unit, the slip ratio from which the coefficient of friction mu between the tire under operation and a road surface changes every moment, and coefficient of friction mu serves as a peak since there are also many noises also changes, and suitable brake control becomes very difficult.
[0018] This invention was made in order to cancel the above-mentioned conventional trouble, and it assumes a model with the large dependence of a system configuration or conditions, and a friction condition is not detected based on a mere oscillation characteristic, a mere displacement response, etc. By making positively the resonance state which reflects frictional force more sensitively, and calculating a friction condition paying attention to the resonance characteristic of this resonance state While there are many noises and they can detect a friction condition correctly also in the situation that a friction condition changes every moment, it aims at offering the friction condition detection equipment of the large simple configuration of applicability.

[Translation done.]

MEANS

[Means for Solving the Problem] In order to attain the above-mentioned purpose, invention of claim 1 the one side side element of the contact surface which frictional force produces -- this contact surface and abbreviation -- according to the vibration system which connects the spring element displaced in the parallel direction, and comes to connect an inertial field with the other end of this spring element, and the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency An exciting-force generating means to excite said vibration system, and an excitation response detection means to detect the quantity of state of the excitation response of vibration system by which excitation was carried out with this exciting-force generating means, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means.
[0020] invention of claim 2 is connected to the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An external force detection means to detect the quantity of state of said external force, and a condition detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means.
[0021] the one side side element of the contact surface where frictional force produces invention of claim 3 -- this contact surface and abbreviation -- with the vibration system which connects the spring element displaced in the parallel direction, and comes to connect an inertial field with the other end of this spring element According to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency An exciting-force generating means to excite said vibration system in the generating direction of frictional force, and an excitation response detection means to detect the quantity of state of the excitation response of said vibration system by which excitation was carried out with this exciting-force generating means, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a maximum-frictional-force state control means to control said applied force generating means to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to the one side side element of said contact surface, and said resonance characteristic operation means.
[0022] invention of claim 4 is connected to the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An external force detection means to detect the quantity of state of said external force, and a condition detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means

to calculate the resonance characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a maximum-frictional-force state control means to control said applied force generating means to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to the one side side element of said contact surface, and said resonance characteristic operation means.

[0023] Invention of claim 5 is constituted based on the applied force when changing into a condition just before said contact surface starts with the maximum-frictional-force state control means of claim 3 or claim 4, including further a maximum-frictional-force operation means to calculate the value of the maximum frictional force in said contact surface, and a coefficient-of-friction operation means to calculate coefficient of friction of said contact surface based on the value of the maximum frictional force calculated with this maximum-frictional-force operation means.

[Translation done.]

OPERATION

[Function] First, vibration system 15 of drawing 8 is used as a model, and the principle of this invention is explained. As shown in drawing 8 , vibration system 15 is mass Ma. An inertial field 11 and mass Mb which contacts through this inertial field 11 and contact surface 10 Mass Mc attached in the spring element 13 of spring constant K attached in the end of an inertial field 12 and an inertial field 11, and the other end of this spring element It consists of inertial fields 14.
[0025] since an inertial field 12 interlocks and vibration system 15 vibrates to vibration of an inertial field 11 in the condition that the contact surface 10 is not [the frictional force generated in the contact surface 10] slippery within the maximum frictional force -- the spring and mass Mc of mass (Ma+Mb) and spring constant K from -- it becomes becoming two systems of inertia and equivalence. Therefore, resonance frequency f1 in the vibration system 15 in case frictional force is less than the maximum frictional force f1 =root {(Ma+Mb+Mc) K/(Ma+Mb) Mc} /2pi ... (2)
It becomes. Moreover, if the inertial field 12 of another side is the fixed end, the resonance frequency f1 of (2) types is. f1 =root (K/Mc) / 2pi ... (3)
It can be alike and can approximate.
[0026] since [on the other hand,] an inertial field 12 cannot be followed in footsteps of vibration of an inertial field 11 but the effect of the inertia becomes small, after frictional force has started exceeding the maximum frictional force -- vibration system 15 -- mass Ma Mass Mc from -- being equivalent to two becoming systems of inertia -- becoming -- the resonance frequency f2 f2 =root{(Ma+Mc) K/Ma Mc} / 2pi ... (4)
It becomes.
[0027] Here, it is resonance frequency f1 to a direction parallel to the contact surface 10 about this vibration system 15. Or the case where minute vibration is carried out by the exciting force 16 of an about [f1] frequency is assumed. the time of being in the condition that the contact surface 10 is not slippery -- the resonance frequency of vibration system 15 -- f1 it is -- since -- vibration system 15 -- setting -- frequency f1 An oscillating component is amplified. That is, vibration system 15 will be in the resonance state in which an about [frequency f1] oscillating component appears strongly. In addition, there is resonance gain expressed with a ratio with the maximum of the oscillating component of vibration system 15 to the maximum amplitude of exciting force 16 to express the resonance characteristic of vibration system 15. In the case of the resonance state, this resonance gain becomes larger to Haruka than 1, and when it is not the resonance state, it becomes small as compared with the resonance state.
[0028] On the other hand, if it comes until just before frictional force and the force of an opposite direction approach the maximum frictional force and start in the contact surface 10, phase contrast will begin to appear to vibration by exciting force 16, and vibration of an inertial field, and resonance gain will decrease rapidly.
[0029] And when the contact surface 10 shifts to the condition of sliding completely, the resonance frequency of vibration system 15 is f2. Frequency f1 given according to exciting force 16 since it was in agreement An oscillating component is decreased and vibration system 15 stops resonating.
[0030] Moreover, vibration system 15f2 When exciting by the exciting force 16 of a nearby frequency, and it is in the condition that the contact surface 10 is not slippery, and vibration system 15 does not resonate but the contact surface 10 starts, vibration system 15 is a frequency f2. An oscillating component will be in the resonance state which appears strongly.
[0031] Moreover, exciting force 16f1 f2 Although it resonates even when it is any in the condition of sliding with the condition that the contact surface 10 is not sliding on vibration system 15 when both the oscillating components of a nearby frequency are included, the resonance frequency from which the amplitude serves as a peak will change.
[0032] In addition, the model of vibration system with which an above-mentioned inertial field vibrates along with a straight line is easily extensible also to a rotational-vibration system. As shown in drawing 10 as a model of this

rotational-vibration system, there is vibration system constituted by the oscillating phenomenon, i.e., the car body, wheel, and road surface in a wheel when the car equipped with the car body 112 of weight W is running at a rate v. Then, it explains with reference to the model which shows the oscillating phenomenon of this vibration system to drawing 11 modeled equivalent with the wheel revolving shaft.

[0033] Here, although a brake force (damping force) acts on a road surface through the front face of the tread 115 of the tire which touches a road surface, in order that this brake force may act on a car body 112 as reaction from a road surface in fact, the equivalence model 117 of revolving-shaft conversion of a body weight becomes what was connected with a wheel 113 and the opposite side through the friction element 116 between the tread of a tire, and a road surface. This is the same like chassis DYNAMO equipment with the ability of the weight of a car body to be simulated with the mass of the big inertia under a wheel, i.e., a wheel, and the opposite side.

[0034] It is [inertia / of the wheel 113 which contained the tire rim by drawing 10 and drawing 11] JV about the inertia of the equivalence model 117 of K, and mu and revolving-shaft conversion of the weight of a car body 112 of the inertia of a tread 115 in the spring constant of the spring element 114 between Jw, a rim, and a tread 15. If it carries out, the property of the whole system will become like following (5) - (7). [coefficient of friction of the friction element 116 between Jt, a tread 115, and a road surface] In addition, the second degree differential d2 / dt2 below "'" expresses the first degree differential d/dt about time amount, and concerning time amount It expresses with ""."

[0035]

JW thetaw" = -T+K (thetat-thetaw) ... (5)

Jt thetat" = -K(thetat-thetaw)+muWR ... (6)

Jv omegav' = -muWR ... (7)

It is here. ww = thetaw' ... (8)

Jv = R2 W ... (9)

omegav = v/r ... (10)

Come out, and it is and is thetaw. For the angle-of-rotation acceleration of a wheel 113, and ww, the angular rate of rotation of a wheel 113 and thetat are [the angle of rotation of a wheel 113, and thetaw"] the angle of rotation of a tread 115, and thetat". The angle-of-rotation acceleration of a tread 115, and omegav The weight of a car body and R of the angular rate of rotation of revolving-shaft conversion of the car-body equivalence model 117, the damping torque with which T is added to a wheel 113, and W are wheel radii. Braking-torque T is the pressure Pb of a brake bulb in fact. Control performs.

[0036] if it thinks that the tread 115 and the car-body equivalence model 117 are linked directly when the tire grips -- the inertia of the sum of the inertia of the car-body equivalence model 117, and the inertia of a tread 115, and the inertia of a wheel 113 -- resonating -- the resonance wave number f1 of the wheel resonance system at this time f1 =root {(Jw+Jt+Jv) K/Jw} (Jt+Jv) /2pi ... (11)

It becomes a next door, a formula (2), and the completely same format. This condition is a field A1 on drawing 9 . It corresponds.

[0037] When the coefficient of friction mu of a tire approaches Peak mu, the coefficient of friction mu on the front face of a tire stops being able to change easily to slip ratio S, and the component accompanying vibration of the inertia of a tread 115 stops on the contrary, influencing the car-body equivalence model 117. That is, a tread 115 and the car-body equivalence model 117 will be separated equivalent, and a tread 115 and a wheel 113 will cause resonance. Resonance frequency f2 of the wheel resonance system at this time f2 =root {(Jw+Jt) K/Jw Jt} /2pi ... (12)

It becomes a next door, a formula (4), and the completely same format. If this condition corresponds to the field A2 of drawing 9 and generally reaches the point of Peak mu, it changes to field A3 in an instant, and a tire locks it. On the other hand, the peak of the gain of whenever [in resonance frequency / wheel speed] also decreases rapidly just before Peak mu.

[0038] Size relation of each inertia Jt <Jw <Jv ... (13)

Come out, and it is and is this. f1 <f2 ... (14)

It comes to be alike. That is, when a tire results in a lock, the resonance frequency of a wheel resonance system will shift to a RF side. Moreover, change of this resonance frequency is rapidly generated near peak mu.

[0039] A model is simplified and it is the inertia Jt of a tread 115. If a peak mu condition is approached even when it ignores, change of the peak of the resonance frequency of a wheel resonance system and the gain of whenever [wheel speed] takes place, and the same analysis is possible for it.

[0040] As mentioned above, the resonance characteristic which frequency component [the existence of resonance of vibration system 15 or a wheel resonance system, change of resonance frequency, and] of exciting force amplified or declined by what resonance gain according to the friction condition of the contact surface changes a lot. On the

contrary, if this resonance characteristic is detected, friction conditions (condition just before starting etc.), coefficient of friction, etc. of the contact surface can be calculated.

[0041] then, the one side side element of the contact surface which frictional force produces in invention of claim 1 -- this contact surface and abbreviation -- an exciting-force generating means excites the vibration system which connected the spring element displaced in the parallel direction, and connected the inertial field to the other end of this spring element according to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency. in addition, the variation rate of a spring element -- a direction -- the contact surface and abbreviation -- if it is an parallel direction (the inside of the contact surface is included) -- arbitration -- it can set up suitably. Next, an excitation response detection means detects the quantity of state of the excitation response of vibration system by which excitation was carried out. This excitation response is the acceleration of the inertial field by exciting force etc., and has frequency distribution of the oscillating component of acceleration etc. as this quantity of state. Next, a resonance characteristic operation means calculates the resonance characteristic of said vibration system based on the quantity of state of exciting force, and the quantity of state of the detected excitation response. And a friction condition operation means calculates the friction condition in said contact surface based on the calculated resonance characteristic. According to this calculated friction condition, it can be identified and judged quantitatively whether it is in the condition that the contact surface is not slippery, a condition just before starting, and which condition in the condition of sliding. Moreover, since the resonance characteristic of vibration system is used, there is an advantage that detection sensitivity cannot be highly influenced easily of disturbance, such as a noise.

[0042] In calculating whether it is in a friction condition just before the contact surface 10 starts in the vibration system 15 of drawing 8 in this invention For example, resonance frequency f1 of the vibration system 15 when the contact surface 10 is not slippery Or f1 Vibration system 15 is excited on a nearby frequency. Frequency f1 The resonance gain of the vibrating component is calculated, and when this resonance gain becomes smaller than the 1st reference value, it judges with a condition just before a friction condition starts. Moreover, resonance frequency f2 when the contact surface is slippery It excites, and when the resonance gain of the component which vibrates on this frequency becomes larger than the 2nd reference value, you may judge with a condition just before starting. Furthermore, it is resonance frequency f1 at least. And f2 It may excite by the exciting force containing two oscillating components, and a friction condition may be calculated based on the value change of resonance frequency.

[0043] Moreover, when the external force which has frequency characteristics, such as white noise, in vibration system has always inputted, even if it does not give exciting force with an exciting-force generating means, vibration system vibrates by the resonance characteristic peculiar to a friction condition.

[0044] So, in invention of claim 2, an external force detection means detects the quantity of state of external force, and a response oscillating detection means detects the quantity of state of response vibration of the vibration system over external force. Next, a resonance characteristic operation means calculates the resonance characteristic based on the detected external force and the quantity of state of response vibration. And a friction condition operation means calculates the friction condition in the contact surface based on the calculated resonance characteristic. Thus, when vibration system causes resonance by external force, an exciting-force generating means can be omitted and equipment can be constituted simply.

[0045] Moreover, the principle of the friction condition detection based on the above resonance characteristics is applicable also to the equipment controlled to hold a condition, i.e., the maximum frictional force, just before the contact surface starts.

[0046] So, in invention of claim 3, an exciting-force generating means excites vibration system according to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency. Next, an excitation response detection means detects the quantity of state of the excitation response of vibration system by which excitation was carried out, and a resonance characteristic operation means calculates the resonance characteristic of vibration system based on the quantity of state of exciting force, and the quantity of state of the detected excitation response. Moreover, applied force is given to the one side side element of the contact surface by the applied force generating means, and this applied force is controlled by the maximum-frictional-force state control means to be in a condition just before the contact surface starts based on the calculated resonance characteristic. This grasps a load, and since the retention span (applied force) which grasps a load with the equipment to which lift up and it is made to move is controlled to be in a friction condition just before the contact surface with a load starts, a possibility of destroying a load superfluously at a big retention span is avoidable. In addition, there is damping force like a brake force which acts on the driving force for rotating a wheel etc. other than a retention span, a wheel, etc. as a mode of this applied force. If a brake force is controlled to be in a condition just before the friction condition of a wheel and a road surface starts, it is applicable also to an anti-lock brake control unit.

[0047] Moreover, when the external force which has frequency characteristics, such as white noise, in vibration system like invention of claim 2 has always inputted, even if it does not give exciting force with an exciting-force generating means, vibration system vibrates by the resonance characteristic peculiar to a friction condition.
[0048] So, in invention of claim 4, an external force detection means detects the quantity of state of external force, and a response oscillating detection means detects the quantity of state of response vibration of the vibration system over external force. Next, a resonance characteristic operation means calculates the resonance characteristic based on the detected external force and the quantity of state of response vibration. Moreover, applied force is given to the one side side element of the contact surface by the applied force generating means, and this applied force is controlled by the maximum-frictional-force state control means to be in a condition just before the contact surface starts based on the calculated resonance characteristic. Thus, when vibration system causes resonance by external force, an exciting-force generating means can be omitted and equipment can be constituted simply.
[0049] Moreover, when applied force is controlled to be held like invention of claim 3 or claim 4 at a condition just before the contact surface starts, the force generated in the contact surface according to this applied force turns into force equal to the maximum frictional force. Therefore, the value of the maximum frictional force can be calculated based on applied force. Furthermore, if the value of the maximum frictional force is known, a coefficient of friction of rest will be called for by doing the division of this by the self-weight of equipment.
[0050] So, in invention of claim 5, the value of the maximum frictional force in the contact surface is calculated with a maximum-frictional-force operation means based on the applied force when changing into a condition just before the contact surface starts. And based on the value of the calculated maximum frictional force, a coefficient of friction of rest is calculated with a coefficient-of-friction operation means. Even when coefficient of friction measures by this on the road surface which changes every moment, a coefficient of friction of rest can be detected correctly and continuously.

[Translation done.]

EXAMPLE

[Example]

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the external view of the load grasping equipment concerning the 1st example of this invention, and (A) shows a front view and (B) shows a side elevation.
[Drawing 2] It is the detailed configuration and configuration block Fig. of the grasping section of load grasping equipment concerning the 1st example.
[Drawing 3] It is the external view of the coefficient-of-friction measuring device concerning the 2nd example of this invention, and (A) shows a front view and (B) shows a side elevation.
[Drawing 4] It is the model and configuration block Fig. of the coefficient-of-friction measuring device concerning the 2nd example which carried out revolving-shaft conversion.
[Drawing 5] It is the diagram showing the property over the slip velocity of damping force/driving force.
[Drawing 6] It is the modification of the coefficient-of-friction measuring device concerning the 2nd example, and (A) shows a front view and (B) shows a side elevation.
[Drawing 7] It is drawing showing the relation between external force and the maximum frictional force.
[Drawing 8] It is drawing showing the equivalence model of the vibration system for explaining the principle of the friction condition detection using the resonance characteristic.
[Drawing 9] It is the diagram showing the property over slip ratio S of the coefficient of friction mu between a tire and a road surface.
[Drawing 10] It is drawing showing the dynamics model of a car.
[Drawing 11] It is drawing showing the model which carried out the revolving-shaft conversion of the dynamics model of a car.
[Description of Notations]
67 Exciting-Force Generating Means
68 Excitation Response Detection Means
69 Resonance Characteristic Operation Means
70 Friction Condition Operation Means
71 Damping Force / Driving Force Operation Means
72 Coefficient-of-Friction Operation Means

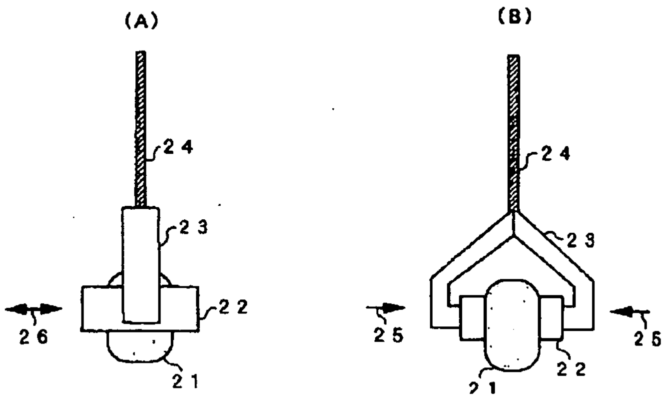
[Translation done.]

* NOTICES *

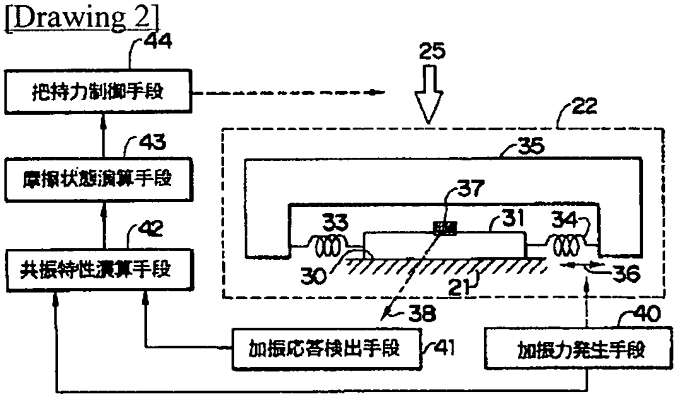
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

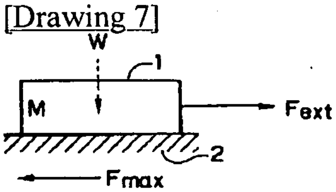
[Drawing 1]



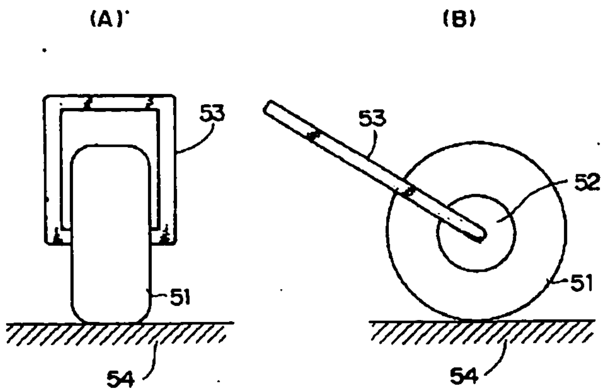
[Drawing 2]



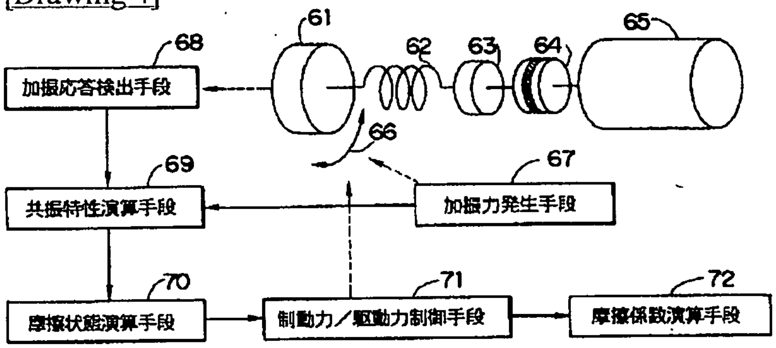
[Drawing 7]



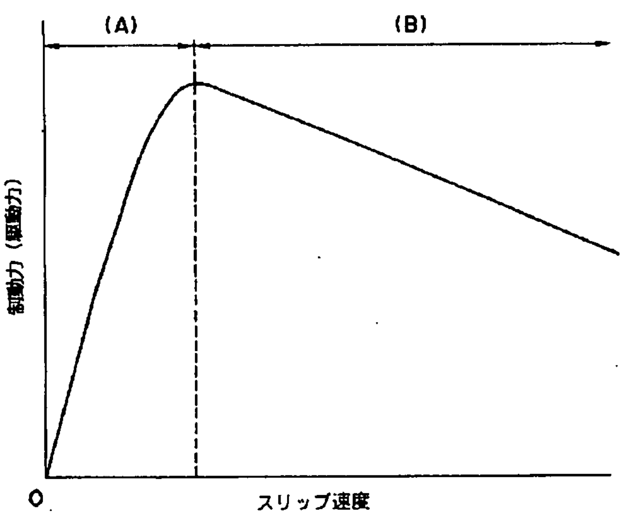
[Drawing 3]



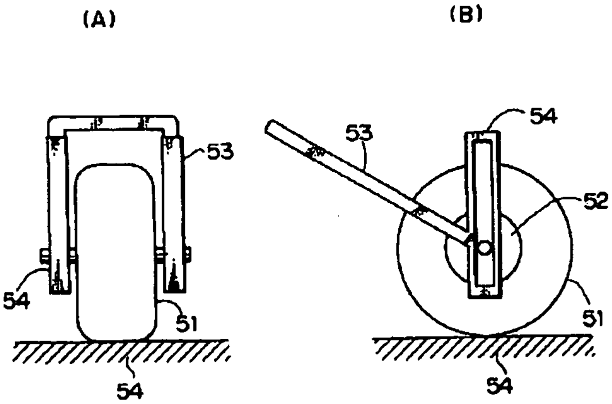
[Drawing 4]



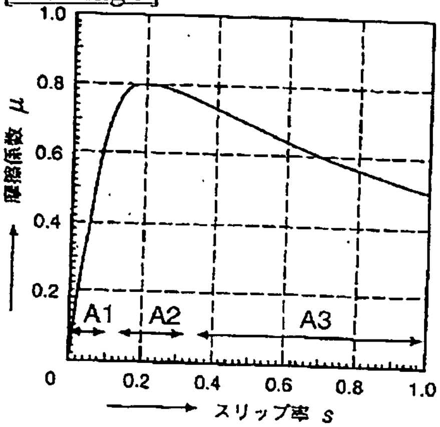
[Drawing 5]



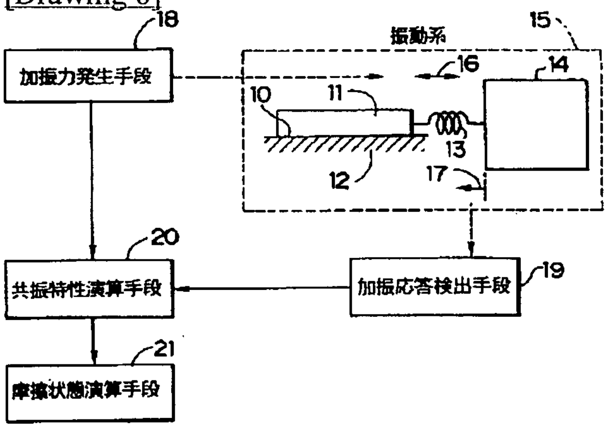
[Drawing 6]



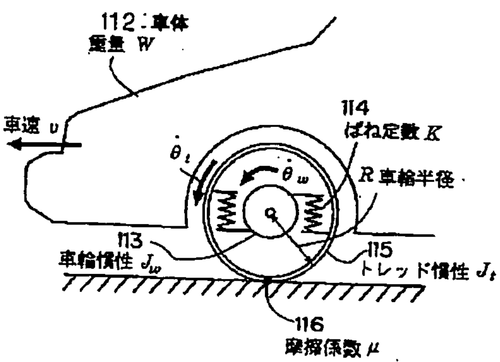
[Drawing 9]



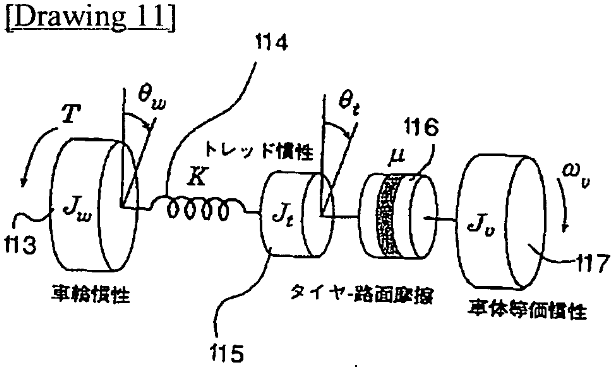
[Drawing 8]



[Drawing 10]



[Drawing 11]



[Translation done.]

1. Amendment August 3, Heisei 13 (2001)

[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 1st partition of the 6th section
[Publication date] August 3, Heisei 13 (2001. 8.3)

[Publication No.] JP,8-334454,A
[Date of Publication] December 17, Heisei 8 (1996. 12.17)
[Annual volume number] Open patent official report 8-3345
[Application number] Japanese Patent Application No. 7-138307
[The 7th edition of International Patent Classification]

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G01N  19/02

B22D  11/16    104
105
B62D   6/00
G01N   3/56
// B62D 137:00
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[FI]

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G01N  19/02        C
B
B22D  11/16    104 A
105
B62D   6/00
G01N   3/56        G
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[Procedure revision]
[Filing Date] August 29, Heisei 12 (2000. 8.29)
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] The name of invention
[Method of Amendment] Modification
[Proposed Amendment]
[Title of the Invention] Friction condition detection equipment and power-steering equipment
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] the one side side element of the contact surface which frictional force produces -- this contact surface and abbreviation -- vibration system which connected the spring element displaced in the parallel direction, and connected the inertial field to the other end of this spring element An exciting-force generating means to excite said vibration

system according to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency,
An excitation response detection means to detect the quantity of state of the excitation response of vibration system by which excitation was carried out with this exciting-force generating means,
A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means,
A friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means,
****** friction condition detection equipment.
[Claim 2] it connects with the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- the vibration system in which consists of a spring element displaced in the parallel direction, and an inertial field connected to the other end of this spring element, and excitation is carried out by external force,
An excitation response detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force,
A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the excitation response detected by said excitation response detection means,
A friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means,
****** friction condition detection equipment.
[Claim 3] the one side side element of the contact surface which frictional force produces -- this contact surface and abbreviation -- the vibration system which connected the spring element displaced in the parallel direction, and connected the inertial field to the other end of this spring element,
An exciting-force generating means to excite said vibration system in the generating direction of frictional force according to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency,
An excitation response detection means to detect the quantity of state of the excitation response of said vibration system by which excitation was carried out with this exciting-force generating means,
A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means,
An applied force generating means to give applied force to said contact surface,
A maximum-frictional-force state control means to control said applied force to be in a condition just before said contact surface starts based on the resonance characteristic calculated with said resonance characteristic operation means,
****** friction condition detection equipment.
[Claim 4] it connects with the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- the vibration system in which consists of a spring element displaced in the parallel direction, and an inertial field connected to the other end of this spring element, and excitation is carried out by external force,
An external force detection means to detect the quantity of state of said external force,
An excitation response detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force,
A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means,
An applied force generating means to give applied force to said contact surface,
A maximum-frictional-force state control means to control said applied force to be in a condition just before said contact surface starts based on the resonance characteristic calculated with said resonance characteristic operation means,
****** friction condition detection equipment.
[Claim 5] A maximum-frictional-force operation means to calculate the value of the maximum frictional force in said contact surface based on the applied force when changing into a condition just before said contact surface starts with

said maximum-frictional-force state control means,
A coefficient-of-friction operation means to calculate coefficient of friction of said contact surface based on the value of the maximum frictional force calculated with this maximum-frictional-force operation means,
Friction condition detection equipment of claim 3 or claim 4 included in a pan.
[Claim 6] Power-steering equipment which performs control which judges the time of a revolution condition turning into the critical state to be road surface coefficient of friction measured by friction condition detection equipment according to claim 5 based on the lateral acceleration under transit, and changes the control force of power steering into usually different magnitude from the time at this time.
[Claim 7] Said resonance characteristic operation means is friction condition detection equipment of claim 2 which detects the resonance characteristic from the detected oscillating component when external force with frequency characteristics like white noise is always inputted as disturbance.
[Claim 8] Said resonance characteristic operation means is claim 2 which searches for the resonance characteristic from the response waveform to this input when impulse-or step-external force is inputted frequently, or friction condition detection equipment of 4.
[Claim 9] Friction condition detection equipment of claims 1, 2, and 3 which vibration system is resonated by the exciting force which contains all the resonance frequency of the vibration system corresponding to each friction condition by said excitation, calculate change of the resonance frequency of the maximum amplitude in a resonance band with said resonance characteristic operation means, and detect the resonance characteristic, or claim 7.
[Claim 10] Said resonance characteristic operation means is claims 1 and 2 which calculate change of the resonance characteristic expressed with the ratio of an excitation response of vibration system to the amplitude of said exciting force as the resonance characteristic of said vibration system, or friction condition detection equipment of 3.
[Claim 11] Said vibration system is friction condition detection equipment of claim 7-10 which is the rotational-vibration system constituted by a car body, a wheel, and the road surface given in any 1 term.
[Claim 12] Said vibration system is friction condition detection equipment including the inertia of the inertia of the wheel containing a tire rim, the spring element between a rim and a tread, the inertia of a tread, the friction element between a tread and a road surface, and the equivalence model of revolving-shaft conversion of the weight of a car body according to claim 11.
[Procedure amendment 3]
[Document to be Amended] Specification
[Item(s) to be Amended] 0020
[Method of Amendment] Modification
[Proposed Amendment]
[0020] invention of claim 2 is connected to the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An excitation response detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a friction condition operation means to calculate the friction condition in said contact surface based on the resonance characteristic calculated with this resonance characteristic operation means.
[Procedure amendment 4]
[Document to be Amended] Specification
[Item(s) to be Amended] 0021
[Method of Amendment] Modification
[Proposed Amendment]
[0021] the one side side element of the contact surface where frictional force produces invention of claim 3 -- this contact surface and abbreviation -- with the vibration system which connects the spring element displaced in the parallel direction, and comes to connect an inertial field with the other end of this spring element According to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency An exciting-force generating means to excite said vibration system in the generating direction of frictional force, and an excitation response detection means to detect the quantity of state of the excitation response of said vibration system by which excitation was carried out with this exciting-force generating means, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of

state of the exciting force generated by said exciting-force generating means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a maximum-frictional-force state control means to control said applied force to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to said contact surface, and said resonance characteristic operation means.
[Procedure amendment 5]
[Document to be Amended] Specification
[Item(s) to be Amended] 0022
[Method of Amendment] Modification
[Proposed Amendment]
[0022] invention of claim 4 is connected to the one side side element of the contact surface which frictional force produces -- having -- this contact surface and abbreviation -- with the spring element displaced in the parallel direction The vibration system in which consists of an inertial field connected to the other end of this spring element, and excitation is carried out by external force, An external force detection means to detect the quantity of state of said external force, and an excitation response detection means to detect the quantity of state of the excitation response of said vibration system in which excitation was carried out by said external force, A resonance characteristic operation means to calculate the resonance characteristic of said vibration system based on the quantity of state of the external force detected by said external force detection means, and the quantity of state of the excitation response detected by said excitation response detection means, It is constituted including a maximum-frictional-force state control means to control said applied force to be in a condition just before said contact surface starts based on the resonance characteristic calculated with an applied force generating means to give applied force to said contact surface, and said resonance characteristic operation means.
[Procedure amendment 6]
[Document to be Amended] Specification
[Item(s) to be Amended] 0025
[Method of Amendment] Modification
[Proposed Amendment]
[0025] since an inertial field 12 interlocks and vibration system 15 vibrates to vibration of an inertial field 11 in the condition that the contact surface 10 is not [the frictional force generated in the contact surface 10] slippery within the maximum frictional force -- the spring and mass Mc of mass (Ma+Mb) and spring constant K from -- it becomes becoming two systems of inertia and equivalence. therefore, resonance frequency f1 in the vibration system 15 in case frictional force is less than the maximum frictional force **
f1 =root {(Ma+Mb+Mc) K/(Ma+Mb) Mc} /2pi
... (2)
It becomes. Moreover, if the inertial field 12 of another side is the fixed end, the resonance frequency f1 of (2) types is,
f1 =root (K/Mc) / 2pi ... (3)
**** __ **
[Procedure amendment 7]
[Document to be Amended] Specification
[Item(s) to be Amended] 0026
[Method of Amendment] Modification
[Proposed Amendment]
[0026] since [on the other hand,] an inertial field 12 cannot be followed in footsteps of vibration of an inertial field 11 but the effect of the inertia is lost, after frictional force has started exceeding the maximum frictional force -- vibration system 15 -- mass Ma Mass Mc from -- two becoming systems of inertia are equivalent -- becoming -- the resonance frequency f2 **
f2 =root {(Ma+Mc) K/Ma Mc} /2pi ... (4)
It becomes.
[Procedure amendment 8]
[Document to be Amended] Specification
[Item(s) to be Amended] 0027
[Method of Amendment] Modification
[Proposed Amendment]
[0027] Here, it is resonance frequency f1 to a direction parallel to the contact surface 10 about this vibration system 15.

Or the case where minute vibration is carried out by the exciting force 16 of an about [f1] frequency is assumed. the time of being in the condition that the contact surface 10 is not slippery -- the resonance frequency of vibration system 15 -- f1 it is -- since -- vibration system 15 -- setting -- frequency f1 An oscillating component is amplified. That is, vibration system 15 will be in the resonance state in which an about [frequency f1] oscillating component appears strongly. In addition, there is resonance gain expressed with the ratio of the amplitude of vibration system 15 to the amplitude of exciting force 16 to express the resonance characteristic of vibration system 15. In the case of the resonance state, this resonance gain becomes large, and when it is not the resonance state, it becomes small as compared with the resonance state.

[Procedure amendment 9]
[Document to be Amended] Specification
[Item(s) to be Amended] 0028
[Method of Amendment] Modification
[Proposed Amendment]

[0028] On the other hand, if it comes until just before frictional force and the force of an opposite direction approach the maximum frictional force and start in the contact surface 10, resonance gain will decrease rapidly.

[Procedure amendment 10]
[Document to be Amended] Specification
[Item(s) to be Amended] 0037
[Method of Amendment] Modification
[Proposed Amendment]

[0037] When the coefficient of friction mu of a tire approaches Peak mu, the coefficient of friction mu on the front face of a tire stops being able to change easily to slip ratio S, and the component accompanying vibration of the inertia of a tread 115 stops on the contrary, influencing the car-body equivalence model 117. That is, a tread 115 and the car-body equivalence model 117 will be separated equivalent, and a tread 115 and a wheel 113 will cause resonance. resonance frequency f2 of the wheel resonance system at this time **

f2 =root {(Jw+Jt) K/Jw Jt} /2pi ... (12)

It becomes a next door, a formula (4), and the completely same format. If this condition corresponds to the field A2 of drawing 9 and generally reaches the point of Peak mu, it changes to field A3 in an instant, and a tire locks it. On the other hand, the gain of whenever [in resonance frequency / wheel speed] also decreases rapidly just before Peak mu.

[Procedure amendment 11]
[Document to be Amended] Specification
[Item(s) to be Amended] 0039
[Method of Amendment] Modification
[Proposed Amendment]

[0039] A model is simplified and it is the inertia Jt of a tread 115. If a peak mu condition is approached even when it ignores, change of the resonance frequency of a wheel resonance system and the resonance gain of whenever [wheel speed] takes place, and the same analysis is possible for it.

[Procedure amendment 12]
[Document to be Amended] Specification
[Item(s) to be Amended] 0042
[Method of Amendment] Modification
[Proposed Amendment]

[0042] In calculating whether it is in a friction condition just before the contact surface 10 starts in the vibration system 15 of drawing 8 in this invention For example, resonance frequency f1 of the vibration system 15 when the contact surface 10 is not slippery Or f1 Vibration system 15 is excited on a nearby frequency. Frequency f1 The resonance gain of the vibrating component is calculated, and when this resonance gain becomes smaller than the 1st reference value, it judges with a condition just before a friction condition starts. Moreover, resonance frequency f2 when the contact surface is slippery It excites, and when the resonance gain of the component which vibrates on this frequency becomes larger than the 2nd reference value, you may judge with a condition just before starting. Furthermore, it is resonance frequency f1 at least. And f2 It may excite by the exciting force containing two oscillating components, and a friction condition may be calculated based on change of a resonance frequency component.

[Procedure amendment 13]
[Document to be Amended] Specification
[Item(s) to be Amended] 0044

[Method of Amendment] Modification
[Proposed Amendment]
[0044] So, in invention of claim 2, a response oscillating detection means detects the quantity of state of response vibration of the vibration system over external force. Next, a resonance characteristic operation means calculates the resonance characteristic based on the quantity of state of response vibration. And a friction condition operation means calculates the friction condition in the contact surface based on the calculated resonance characteristic. Thus, when vibration system causes resonance by external force, an exciting-force generating means can be omitted and equipment can be constituted simply.
[Procedure amendment 14]
[Document to be Amended] Specification
[Item(s) to be Amended] 0046
[Method of Amendment] Modification
[Proposed Amendment]
[0046] So, in invention of claim 3, an exciting-force generating means excites vibration system according to the exciting force containing the resonance frequency of this vibration system, or the oscillating component near the resonance frequency. Next, an excitation response detection means detects the quantity of state of the excitation response of vibration system by which excitation was carried out, and a resonance characteristic operation means calculates the resonance characteristic of vibration system based on the quantity of state of exciting force, and the quantity of state of the detected excitation response. Moreover, applied force is given to the one side side element of the contact surface by the applied force generating means, and this applied force is controlled by the maximum-frictional-force state control means to be in a condition just before the contact surface starts based on the calculated resonance characteristic. This grasps a load, and since the retention span (applied force) which grasps a load with the equipment to which lift up and it is made to move is controlled to be in a friction condition just before the contact surface with a load starts, a possibility of destroying a load superfluously at a big retention span is avoidable. In addition, there is damping force which acts on the driving force for rotating a wheel etc. other than a retention span, a wheel, etc. as a mode of this applied force. If a brake force is controlled to be in a condition just before the friction condition of a wheel and a road surface starts, it is applicable also to an anti-lock brake control unit.
[Procedure amendment 15]
[Document to be Amended] Specification
[Item(s) to be Amended] 0059
[Method of Amendment] Modification
[Proposed Amendment]
[0059] Moreover, a resonance characteristic operation means 42 to calculate the resonance characteristic of the grasping section 22 which grasped the load 21 based on response characteristics, such as the exciting force 36 given by the exciting-force generating means 40 and the acceleration 38 detected by the excitation response detection means 41, is established. This resonance characteristic is expressed with the ratio (resonance gain) of the amplitude of the oscillating component of acceleration 38 to the amplitude of exciting force 36, change of resonance frequency, etc.
[Procedure amendment 16]
[Document to be Amended] Specification
[Item(s) to be Amended] 0077
[Method of Amendment] Modification
[Proposed Amendment]
[0077] Next, the resonance characteristic operation means 69 is resonance frequency f1 as the resonance characteristic. The amplitude value of an oscillating component is calculated. This is effective when the amplitude of the excitation torque 66 always takes constant value. In addition, you may ask for a ratio (resonance gain) with the amplitude of the oscillating component of the rotational speed to the amplitude of the excitation torque 66 like the 1st example.
[Procedure amendment 17]
[Document to be Amended] Specification
[Item(s) to be Amended] 0084
[Method of Amendment] Modification
[Proposed Amendment]
[0084] As mentioned above, it is held at a condition just before the friction condition of the contact surface is slippery by controlling to make damping force/driving force increase, when it judges with the contact surface 64 not being slippery, and controlling to decrease damping force/driving force, when it judges with the contact surface 64 being

slippery. That is, the value of the force applied to the tread of a tire with damping force/driving force is maintained so that it may become a value near [in the contact surface 64] the maximum frictional force.

[Translation done.]